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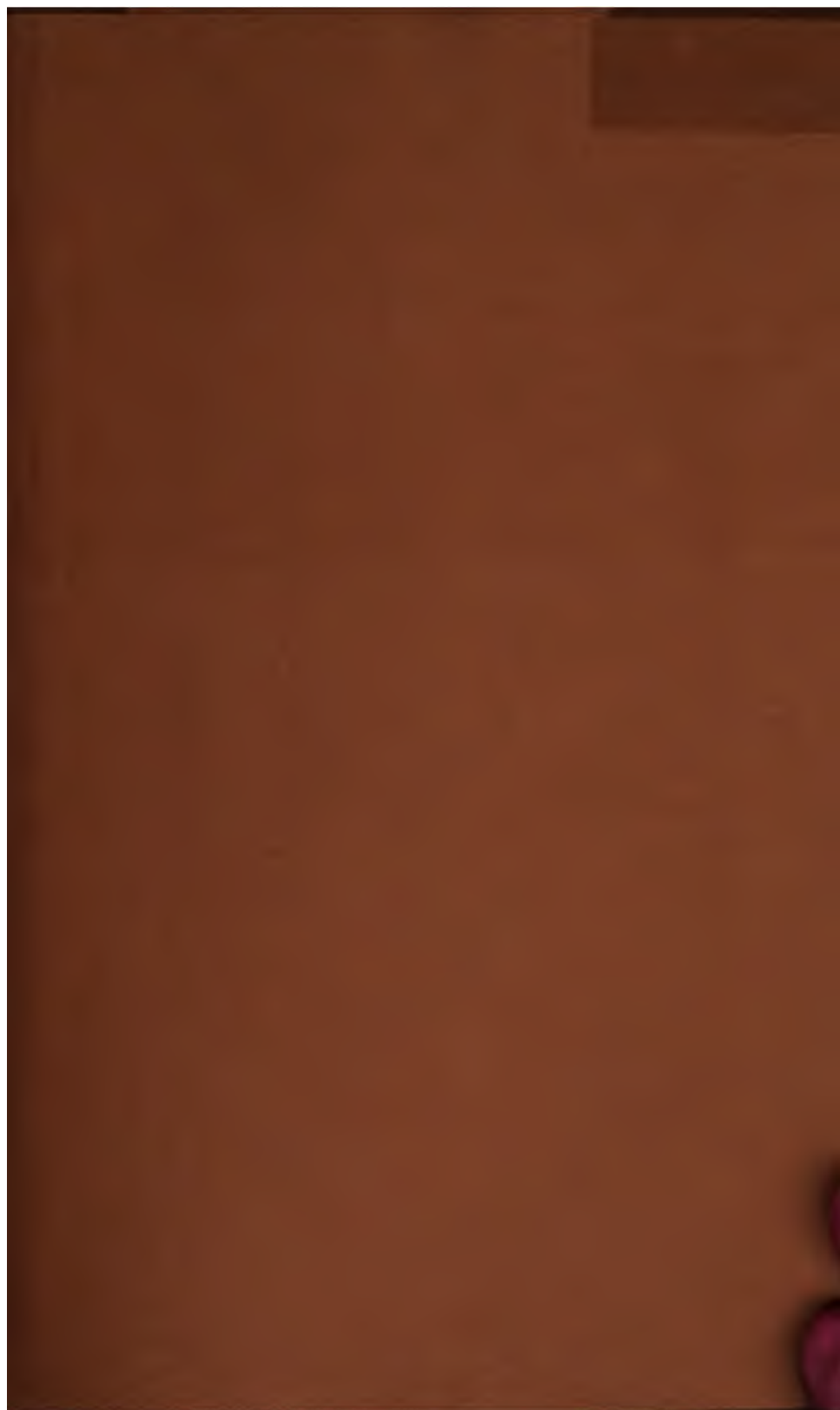
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## APPENDIX TO ANNUAL REPORT.

### No. I.

#### LIST OF FELLOWS CORRECTED TO JUNE 1, 1871.

*Fellows are requested to correct errors in this List, by letter to the Hon. Secretaries, 35, Trinity College, Dublin; or to the Assistant Secretary.*

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#### HONORARY FELLOWS.

##### Elected.

- |       |     |  |
|-------|-----|--|
| 1844. | 1.  | Boué, M. Ami, For. Mem., L. G. S., <i>Paris</i> .                                  |
| 1865. | 2.  | Burton, Captain, R. F., H. M. Consul, <i>Santoz</i> .                              |
| 1861. | 3.  | Daubrée, M., Membre d l'Institut, 91, <i>Rue de Gréville, St. Germain, Paris</i> . |
| 1861. | 4.  | Delesse, M. Ingénieur des Mines, <i>Paris</i> .                                    |
| 1865. | 5.  | Des Cloiseaux, M., Prof. of Mineralogy, <i>Jardin des Plantes, Paris</i> .         |
| 1861. | 6.  | De Serres, M. Marcel, <i>Montpelier</i> .  |
| 1861. | 7.  | Déville, M. C. Ste Claire, <i>Paris</i> .  |
| 1861. | 8.  | Déville, M. H. Ste Claire, <i>Paris</i> .  |
| 1861. | 9.  | De Koninck, M. L., For. Mem. L. G. S., <i>Liège</i> .                              |
| 1861. | 10. | Geinitz, M. H. B., For. Mem., L. G. S., <i>Dresden</i> .                           |
| 1863. | 11. | Hunt, Dr. T. Sterry, F. R. S., <i>Montreal</i> .                                   |
| 1844. | 12. | Lyell, Sir Charles, F. L. S., 73, <i>Harley-street, London, W</i> .                |
| 1861. | 13. | M'Clintock, Sir Leopold, R. N., 21, <i>Merrion-square, North</i> .                 |
| 1844. | 14. | Murchison, Sir Roderick I., F. R. S., 16, <i>Belgrave-square, London, S</i> .      |
| 1832. | 15. | Sedgwick, Rev. A., F. R. S., <i>Cambridge</i> .                                    |

## HONORARY CORRESPONDING FELLOWS.

## Elected.

1859. 1. Gordon, John, C. E., *India*.
1859. 2. Hargrave, Henry, J. B., C. E., *India*.
1859. 3. Hime, John, C. E., *Ceylon*.
1858. 4. Kingsmill, Thomas W., *Hong Kong*.
1855. 5. Medlicott, Joseph, *India*.
1854. 6. Oldham, Thomas, F. R. S., *Calcutta*.

## FELLOWS WHO HAVE PAID LIFE COMPOSITION.

1853. 1. Allen, Richard Purdy, 10, *Beesboro'-terrace, North Circular Road*.
1861. 2. Armstrong, Andrew, 16, *D'Olier-street*.
1857. 3. Carson, Rev. Joseph, D. D., S. F. T. C. D., *Trinity College*.
1857. 4. Dowse, Richard, *Mountjoy-square*,
1861. 5. Fottrell, Edward, *Fleet-street*.
1862. 6. Frazer, W., M. D., M. R. I. A., 20, *Harcourt-street*.
1857. 7. Greene, John Ball, 6, *Ely-place*.
1848. 8. Haughton, Rev. Professor, M. D., F. R. S., 40, *Trinity College*.
1862. 9. Henry, F. H., *Lodge Park, Straffan, Co. Kildare*.
1850. 10. Hone, Nathaniel, M. R. I. A., *St. Douglough's, Co. Dublin*.
1861. 11. Hone, Thomas, *Yapton, Monkstown, Co. Dublin*.
1831. 12. Hutton, Robert, F. G. S., *Putney Park, London*.
1867. 13. Kane, Sir R., 51, *Stephen's-green*.
1866. 14. Lalor, J. J., 6, *Upper Fitzwilliam-street*.
1856. 15. Lentaigue, John, M. D., *Great Denmark-street*.
1851. 16. Malahide, Lord Talbot de, F. R. S., *Malahide Castle, Malahide*.
1867. 17. Malet, Rev. J. A., D. D., S. F. T. C. D., *Trinity College*.
1838. 18. Mallet, Robert, C. E., F. R. S., *The Grove, Clapham-road, London*.
1846. 19. Murray, B. B., *County Survey Office, Downshire-road, Newry*.
1859. 20. Ogilby, William, F. G. S., *Lisoleen, Dunmanagh, Co. Tyrone*.
1852. 21. O'Kelly, Joseph, 14, *Hume-street*.
1849. 22. Sidney, F. J., LL. D., 19, *Herbert-street*.
1864. 23. Symes, Richard Glascott, 14, *Hume-street*.
1851. 24. Whitty, John Irvine, LL. D., 35, *Lower Mount-street*.

## FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.\*

1868. 1. Backhouse, M., 2, *Ontario-terrace*.
1854. 2. Barnes, Edward, *Ballymurtagh, Co. Wicklow*.
1866. 3. Bradley, Samuel, *Little Castle, Castlecomer*.
1832. 4. Bryce, James, LL. D., M. A., F. G. S., *High School, Glasgow*.
1862. 5. Carter, T. S., *Watlington Park, Watlington, Oxfordshire*.
1854. 6. Clemes, John.
1870. 7. Cooke, Samuel, C. E., *Poona, Civil Engineering College, Bombay*.
1857. 8. Crawford, Robert, C. E., *care of Messrs. Peto and Betts, 9, Great George's-street, Westminster, S. W.*
1861. 9. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee*.
1866. 10. Duffin, W. E. L'Estrange, *Maghera Rectory, Co. Down*.

## \* EXTRACT FROM BY-LAWS.

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## Elected.

1861. 11. Dunally, Lorfi, *Kilboy, Nenagh.*
1832. 12. Dunraven, Earl of, F. R. S., *Adare, Co. Limerick.*
1866. 13. Ellis, R. H., *The Hill, Monkstown.*
1871. 14. Emerson, Rev. J. M., *Timahoe.*
1869. 15. Enniskillen, Earl of, F. R. S., M. R. I. A., *Florence Court, Enniskillen.*
1866. 16. Graves, S. R., M. P., *Wavertree, Liverpool.*
1853. 17. Harkness, Professor, F. R. S., *Queen's College, Cork.*
1861. 18. Harte, W., C. E., *Buncrana, Donegal.*
1856. 19. Haughton, Lieut. John, R. A., *Bengal.*
1850. 20. Head, Henry, M. D., 7, *Fitzwilliam-square.*
1858. 21. Hill, J., C. E., *Ennis, Co. Clare.*
1862. 22. Hudson, R., F. R. S., F. L. S., *Clapham Common, London.*
1865. 23. Jacob, Arthur, B. A., *Bromley, Kent.*
1839. 24. James, Sir H., Colonel, R. E., F. R. S., *Ordnance Survey Office, Southampton.*
1832. 25. Kearney, Thomas, *Pallasgreen, Co. Limerick.*
1857. 26. Keane, Marcus, *Beech Park, Ennis, Co. Clare.*
1853. 27. Kinahan, George H., 28, *D'Oli-r-street.*
1862. 28. Kincaid, Joseph, Jun., C. E., 9, *Spring-gardens, London, S. W.*
1838. 29. Larcom, Major-General Sir Thomas, R. E., LL. D., F. R. S., *Heathfield, Fareham, Hants.*
1858. 30. Leech, Lieut.-Colonel, R. E., 3, *St. James's-square, London, S. W.*
1868. 31. Leonard, Hugh, 14, *Hume-street.*
1840. 32. Lindsay, Henry L., C. E., *Melbourne, care of J. Bower, Esq., C. E., 28, South Frederick-street.*
1867. 33. Meadows, J. M'Carthy, *Athy.*
1840. 34. Montgomery, James E., M. R. I. A.
1856. 35. Moloney, C. P., Capt., 25th Regiment, Madras N. I., *per Messrs. Grinlay and Co., 3, Cornhill, London.*
1856. 36. Medicott, Henry B., F. G. S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E. C.*
1857. 37. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, Co. Tyrone.*
1865. 38. Morton, G. H., 7, *London-road, Liverpool.*
1845. 39. Neville, John, C. E., M. R. I. A., *Dundalk.*
1870. 40. Nicholls, Thomas, 32, *North Great George's-street.*
1868. 41. Nolan, Joseph, 14, *Hume-street.*
1832. 42. Renny, Henry L., R. E., *Canada.*
1870. 43. Rigby, Jason, C. E., 49, *Park-avenue, Sandymount.*
1865. 44. Scott, J. M., *Bengal Presidency College, Calcutta.*
1868. 45. Siree, P. H., C. E.
1854. 46. Smyth, W. W., F. R. S., *Jermyn-street, London.*
1865. 47. Steele, Rev. W., *Portora Royal School, Enniskillen.*
1857. 48. Tait, Alexander, C. E., *Queen's Elms, Belfast.*
1870. 49. Taylor, J. E., F. G. S., *Brasondale, Norwich.*
1832. 50. Tighe, Right Hon. William, *Woodstock, Innistogue.*
1866. 51. Townsend, H. W., *Clonakilty.*
1866. 52. Wall, H. P., *Portarlinton.*
1864. 53. Waller, G. A., 94, *Pembroke-road, Ball's-bridge.*
1853. 54. Webster, William B.
1871. 55. Weldon, Captain Frank.
1861. 56. Whitney, C. J., *Brisbane, Queensland.*
1846. 57. Wilson, Walter.
1864. 58. Wright, Joseph, 7, *Donegal-street, Belfast.*
1854. 59. Wyley, Andrew.
1857. 60. Wynne, Arthur B., F. G. S.

## FELLOWS.

## Elected.

1861. 1. Andrews, William, 4, *Nassau-street*.
1867. 2. Baily, W. H., *Hume-street*.
1857. 3. Bandon, Earl of, D. C. L., *Castle Bernard, Bandon, Co. Cork*.
1859. 4. Barker, John, M. D., 83, *Waterloo-road*.
1861. 5. Barrington, C. E., *Fassaroe, Bray*.
1862. 6. Barrington, E., *Fassaroe, Bray*.
1862. 7. Barton, Henry M., 4, *Foster-place*.
1864. 8. Bateman, C. W., LL. D., *West End, Mallow*.
1844. 9. Bective, Earl of, *Headfort, Kells*.
1862. 10. Bennett, E., M. B., 2, *Upper Fitzwilliam-street*.
1857. 11. Bolton, George, Jun., 6, *Ely-place*.
1861. 12. Bolton, H. E., 6, *Ely-place*.
1864. 13. Bradshaw, G. B.
1868. 14. Brien, Charles H., *Board of Public Works, Custom-house*.
1870. 15. Brett, H. C., C. E., 8, *Harrington-street*.
1840. 16. Callwell, Robert, M. R. I. A., 25, *Herbert-place*.
1857. 17. Carte, Alexander, M. D., F. L. S., *Royal Dublin Society*.
1867. 18. Clarke, G. R., *Public Works Department, Lucknow, India*.
1862. 19. Close, Rev. Maxwell, *Newtown Park, Blackrock*.
1858. 20. Cotton, Charles, P., C. E., 11, *Lower Pembroke-street*.
1862. 21. Cousins, A. L., C. E.
1873. 22. Crook, Rev. R., LL. D., *Wesleyan College, Belfast*.
1858. 23. Cruise, R. J., 14, *Hume-street*.
1871. 24. Dargan, James, *Cork and Bandon Railway, Cork*.
1853. 25. De Vesci, Lord, *Abbeyleix House, Abbeyleix*.
1863. 26. Dixon, G., 32, *Holles-street*.
1849. 27. Downing, Samuel, LL. D., C. E., *Trinity College*.
1852. 28. Doyle, J. B., *Derrymore House, Newry*.
1867. 29. Dunscombe, Clement, *King William's Town, Co. Cork*.
1865. 30. Fleming, John M., *The Barracks, Clonmel*.
1866. 31. Foot, A. W., M. D., 21, *Lower Pembroke-street*.
1867. 32. Forster, R., *University Club*.
1858. 33. Gages, Alphonse, M. R. I. A., 51, *Stephen's-green*.
1864. 34. Gahan, A., C. E., *Cavan*.
1849. 35. Galbraith, Rev. Joseph A., F. T. C. D., *Trinity College*.
1865. 36. Gibson, John, C. E., *Stapleton-place, Dundalk*.
1867. 37. Gore, J. E., C. E.
1865. 38. Gray, R. A., C. E., 5, *Palmerstown Villas, Upper Rathmines*.
1859. 39. Green, Murdock, 52, *Lower Sackville-street*.
1862. 40. Gribbon, C. P., 72, *Stephen's-green*.
1831. 41. Griffith, Sir R., Bart., LL. D., F. G. S., 2, *Upper Fitzwilliam-place*.
1857. 42. Hampton, Thomas, C. E., 6, *Ely-place*.
1871. 43. Hardman, E. T., 14, *Hume-street*.
1866. 44. Heron, Robert, *Harrow House, Ballybrack*.
1861. 45. Hudson, A., M. D., *Merrion-square*.
1870. 46. Hull, Edward, M. A., F. R. S., 14, *Hume-street*.
1865. 47. Hutton, T. M., 118, *Summer-hill*.
1852. 48. Jellett, Rev. J., F. T. C. D., M. R. I. A., 9, *Trinity College*.
1842. 49. Jennings, F. M., M. R. I. A., *Brown-street, Cork*.
1871. 50. Kelly, G. N. H., *Fair-street, Drogheda*.
1862. 51. Kinahan, G., J. P., *Roebuck-hill, Dundrum*.
1866. 52. Knapp, W. H., C. E., 5, *Summerhill-road, Kingstown*.
1865. 53. Leech, John, C. E., 6, *Ely-place*.
1831. 54. Lloyd, Rev. Humphrey, D. D., F. R. S., Provost, T. C. D., *Provost's House*.
1863. 55. Macalister, A., M. D., 19, *Leinster-road, Rathmines*.
1855. 56. M'Causland, Dominick, 12, *Fitzgibbon-street*.
1861. 57. M'Comas, A., 23, *Rathmines-road*.
1863. 58. M'Donnell, Alexander, C. E., *St. John's, Inchicore*.
1851. 59. M'Donnell, John, M. D., 4, *Gardiner's-row*.
1837. 60. Mollan, John, M. D., 8, *Fitzwilliam-square*.

## Elected.

1859. 61. Moore, Joseph Scott, J. P., *Hume-street*.  
 1831. 62. Nicholson, John, M. R. I. A., *Bairath House, Kells*.  
 1856. 63. O'Brien, Octavius, 23, *Kildare-street*.  
 1865. 64. Ollis, G., *The Camp, Aldershot*.  
 1864. 65. Palmer, Sandford, *Roscrea*.  
 1857. 66. Porter, William, C. E., *Leinster Club, Clare-street*.  
 1865. 67. Radley, John, *Gresham Hotel, Sackville-street*.  
 1864. 68. Reynolds, J. Emerson, M. D., *Royal Dublin Society*.  
 1857. 69. Reeves, R. S., 22, *Upper Mount-street*.  
 1861. 70. Roberts, W. G., *Nenagh, Co. Tipperary*.  
 1862. 71. Rowan, D. J., O. E., *Athlone*.  
 1864. 72. Russell, H.  
 1852. 73. Smith, Robert, M. D., 63, *Eccles-street*.  
 1854. 74. Scott, Robert H., F. G. S., *Meteorological Office, 116, Victoria-street, London*.  
 1866. 75. Stewart, H., M. D., *Lucan*.  
 1859. 76. Stokes, William, M. D., F. R. S., 5, *Merrion-square, N.*  
 1861. 77. Stoney, Bindon, C. E., 42, *Wellington-road*.  
 1852. 78. Taylor, Colonel Meadows, M. R. I. A., *Oldcourt, Harold's-cross*.  
 1864. 79. Tichborne, C. R. C., *Apothecaries' Hall, Mary-street*.  
 1869. 80. Traquair, R. H., M. D., 51, *Stephen's-green*.  
 1859. 81. Waldron, L., LL.D., *Ballybrack*.  
 1863. 82. Westropp, W. H. S., M. R. I. A., 2, *Idrone-terrace, Blackrock*.  
 1863. 83. Williams, Richard Palmer, 38, *Dame-street*.  
 1851. 84. Wright, Edmund P., LL. D., M. R. I. A., 5, *Trinity College, Dublin*.  
 1871. 85. Wright, Edward P., M. D., 5, *Trinity College*.  
 1871. 86. Warren, J. L., 14, *Hume-street*.

## ASSOCIATES FOR THE YEAR.

1. Clibborn, J., 13, *Leeson-park*.
2. Dwyer, F., 45, *Upper Sackville-street*.
3. Edmondson, J. W., *Fozrock*.
4. Greene, J. F., 63, *Lower Gardiner-street*.
5. Griffith, J. P., 2, *Trinity College*.
6. Heath, F., *Harold's-Cross*.
7. Neville, E. K., 18, *Trinity College*.
8. Purcell, Gervaise, 71, *Harcourt-street*.
9. Ryan, J. H., 34, *Leeson-park*.
10. West, C. D., *St. Patrick's Deanery*.
11. White, H. B., *Royal Dublin Society*.

## No. II.

## LIST OF MEMBERS GAINED AND LOST,

CORRECTED TO JUNE 1, 1871.

## FELLOWS GAINED.

*Half Life Members.*

1. Emerson, Rev. J. M., *Timahoe*.
2. Weldon, Captain F. (Royal Engineers).

*Annual.*

1. Hardman, E. T., Geol. Surv. Ireland, 14, *Hume-street*.
2. Kelly, G. N. H., *Fair-street, Drogheda*.
3. Dargan, James, C. E., *Cork and Bandon Railway, Cork*.
4. Wright, E. P., M. D., Prof. of Botany, T. C. D., 5, *Trinity College*.
5. Warren, J. L., Geol. Surv. Ireland, 14, *Hume-street*.

No. III.

State of the Society :—

	Last Report.	Present Year.
Honorary Fellows, . . . .	15 . . . .	14
Corresponding do., . . . .	6 . . . .	6
Life do., . . . .	84 . . . .	87
Annual, do., . . . .	86 . . . .	89
	<hr/> 191	<hr/> 196

No. IV.

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE  
ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN, . .	University Library.
ALBANY, . . .	State Library, New York.
AMSTERDAM, .	Royal Academy of Sciences.
ANTWERP, . .	Société Paléontologique de Belgique.
BELFAST, . .	Queen's College Library.
	Naturalists' Field Club.
BERLIN, . . .	Royal Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Bessersche Buchhandlung, <i>Behrens-</i> <i>str., 7, Berlin.</i>
BOLOGNA, . .	Accademia delle Scienze delle Istituto.
BORDEAUX, . .	Imperial Academy of Sciences.
BOSTON, . . .	American Academy.
	Natural History Society.
BRISTOL, . . .	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN, . . .	Naturforschende Verein.
BRUSSELS, . .	Academy of Sciences.
CAEN, . . . .	Société Linnéenne Normandie.
CALCUTTA, . .	Asiatic Society.
	Public Library.
	Geological Survey of India.
CAMBRIDGE, .	Philosophical Society.
	Trinity College Library.
CANTERBURY, .	} Geological Survey.
NEW ZEALAND, .	
COPENHAGEN, .	Royal Society of Science
CORK, . . . .	Queen's College, Library.
	Royal Institution.
DIJON, . . . .	Academy of Sciences.
DRESDEN, . . .	The "Isis" Society.
DUBLIN, . . .	Royal College of Surgeons' Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Natural History Society.
	Ordnance Survey Library.
	Professor Sullivan, as Editor of the "Atlantis."
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH, .	Royal Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates' Library.

- ALMOUTH, . . . Royal Cornwall Polytechnic Society.  
FLORENCE, . . . Society of Physics and Natural History.  
GALWAY, . . . Queen's College Library.  
GENOA, . . . Society of Physics.  
GLASGOW, . . . University.  
Geological Society.  
GÖTTINGEN, . . . University.  
HAARLEM, . . . Société Hollandaise des Sciences, per B. Quarritsch, 15, *Piccadilly, London*.  
HALLE, . . . Naturwissenschaftliche Verein für Sachsen und Thüringen, per Antons Buchhandlung, *Halle*.  
HANAU, . . . Oberhessische Gesellschaft der Natur-und Heil-kunde.  
HANOVER, . . . Royal Library.  
KILKENNY, . . . Archaeological Society.  
KÖNIGSBERG, . . . Königlich Physicalisch-Oekonomische Gesellschaft.  
LAUSANNE, . . . Société Vaudois des Sciences Naturelles.  
LEEDS, . . . Geological and Polytechnic Society of the West Riding of Yorkshire.  
Philosophical and Literary Society.  
LEIPZIG, . . . Royal Society of Sciences (Saxony).  
University.  
LIVERPOOL, . . . The Literary and Philosophical Society.  
Historical Society of Lancashire and Cheshire.  
Geological Society, The Royal Institution, *Colquitt-street*.  
LONDON, . . . Geological Survey, *Jermyn-street*.  
British Museum.  
Society of Arts, *John-street, Adelphi*.  
Royal Institution, *Albemarle-street*.  
Royal Society, *Burlington House*.  
Geological Society, *Somerset House*.  
Linnean Society, *Burlington House*.  
Royal Geographical Society, 15, *Whitehall-place*.  
Civil Engineers, Institution of, 25, *Great George's-street, Westminster*.  
Royal Asiatic Society, 5, *New Burlington-street*.  
Royal College of Surgeons, *Lincoln's Inn*.  
Zoological Society, 11, *Hanover-square*.  
Athenæum, 14, *Wellington-street, Strand, London, W. C.*  
Anthropological Society, 4, *St. Martin's-place, London, W. C.*  
LYONS, . . . La Société Impériale d'Agriculture, d'Histoire Naturelle, et des Arts Utiles.  
Société Linnéenne.  
Académie Impériale, per Treuttel & Wurtz, 19, *Rue de Lille, Paris*.  
MADRID, . . . Academia de Ciencias.  
MANCHESTER, . . . Literary and Philosophical Society of. [See R. C. Christie].  
Geological Society.  
MELBOURNE, . . . Philosophical Institute of Victoria.  
The Public Library, per Bain and Co., 1, *Haymarket, London*.  
The Royal Society.  
MILAN, . . . Reale Istituto Lombardo di Scienze.  
MISSOURI, . . . State Survey and University, *Geological Rooms, Columbia, U. S. A.*  
MODENA, . . . Institute of Science.  
MONTREAL, . . . Natural History Society.  
MUNICH, . . . Royal Academy of Science (2 copies).  
Société des Sciences Naturelles.  
NEUCHÂTEL, . . .  
NEW HAVEN, } The Editors of Silliman's Journal of Science and Art.  
U. S. A., }  
NEW YORK, . . . Lyceum of Natural History.  
OXFORD, . . . Bodleian Library.  
Ashmolean Society.  
PALERMO, . . . Accademia di Scienze e Lettere.  
PARIS, . . . Ecole Polytechnique.  
Geological Society.  
L'Ecole Impériale des Mines.  
Institute of France.  
Bibliothèque Impériale.  
Jardin des Plantes, Bibliothèque.

- PALERMO**, . . . Accademia di Scienze e Lettere.  
**PARIS**, . . . Ecole Polytechnique.  
                   Geological Society.  
                   L'Ecole Impériale des Mines.  
                   Institute of France.  
                   Bibliothèque Impériale.  
                   Jardin des Plantes, Bibliothèque.  
**PHILADELPHIA**, American Philosophical Society.  
                   Academy of Natural Sciences, per Trübner and Co.  
**PLYMOUTH**, . . The Plymouth Institution and Devon and Cornwall Natural History  
                   Society.  
**PRESBURG**, . . Der Verein für Naturkunde.  
**QUEBEC**, . . . Literary and Historical Society.  
**ROME**, . . . The Vatican Library.  
**ROUEN**, . . . Academy of Sciences.  
**ST. ANDREWS**, University Library.  
**ST. LOUIS**, . . . Academy of Sciences.  
**ST. PETERSBURG** Imperial Academy.  
                   Central Physical Observatory of Russia.  
                   Russisch-Kaiserliche Mineralogische Gesellschaft.  
**STOCKHOLM**, . . Royal Academy of Science, per Longman and Co., *Paternoster-row*,  
                   *London*; and Sampson and Wallis, *Stockholm*.  
                   Geological Survey of Sweden.  
**STRASBURG**, . . Société des Sciences Naturelles.  
**STUTTGART**, . . Verein für vaterländische Naturkunde.  
**TORONTO, C.W.**, Canadian Institute, per Thomas Henning, Esq.  
**TOULOUSE**, . . Academy of Sciences.  
**TRURO**, . . . Royal Institute of Cornwall.  
**TURIN**, . . . Royal Academy.  
**UPSALA**, . . . Royal Society of Sciences.  
**VIENNA**, . . . Imperial Academy of Sciences.  
                   Prof. W. Haidinger, of Vienna, as Editor of the "Jahrbuch der K.  
                   K. Geologischen Reichsanstalt."  
                   K. K. Zoologisch-botanische Gesellschaft, per Braümüller and Co.,  
                   *Vienna*.  
**WASHINGTON**, Smithsonian Institute Library, per W. Wesley, Esq., 26, *Essex-street*,  
                   *Strand, London*.  
**WINDSOR**, . . The Royal Library.  
**ZURICH**, . . . Naturforschende Gesellschaft.

# APPENDIX TO ANNUAL REPORT.

## No. I.

### LIST OF FELLOWS CORRECTED TO JUNE 1, 1872.

*Fellows are requested to correct errors in this List, by letter to the Hon. Secretaries, 35, Trinity College, Dublin; or to the Assistant Secretary.*

### OFFICERS OF THE SOCIETY FOR THE YEARS 1872-3.

**PRESIDENT.**—Alexander Macalister, M. B.

**VICE-PRESIDENTS.**—Earl of Enniskillen; Colonel Meadows Taylor, M. R. I. A.; J. Emerson Reynolds, Esq.; Rev. H. Lloyd, Provost, T. C. D.; Sir Richard Griffith, Bart., LL. D.

**TREASURERS.**—William Andrews, Esq.; Samuel Downing, LL. D.

**SECRETARIES.**—Rev. S. Haughton, M. D., F. R. S.; Edward Hull, M. A., F. R. S.

**COUNCIL.**—Sir R. Kane, F. R. S.; Alphonse Gages, M. R. I. A.; B. B. Stoney, C. E.; William Frazer, M. D.; Alexander Carte, M. D.; W. H. S. Westropp, M. R. I. A.; C. R. O. Tichborne, Esq.; Rev. Maxwell Close, M. A.; Francis M. Jennings, F. C. S.; R. H. Traquair, M. D.; John Barker, M. D.; John Ball Greene, Esq.; R. A. Gray, C. E.; William H. Baily, F. G. S.; William Ogilby, F. Z. S., F. G. S.

### HONORARY FELLOWS.

*Elected.*

- |       |   |
|-------|---|
| 1844. | 1. Boué, M. Ami, For. Mem., L. G. S., <i>Paris</i> .                                  |
| 1865. | 2. Burton, Captain, R. F., H.M. Consul, <i>Santoz</i> .                               |
| 1861. | 3. Daubrée, M., Membre d l'Institut, 91, <i>Rue de Gréville, St. Germain, Paris</i> . |
| 1861. | 4. Delesse, M. Ingénieur des Mines, <i>Paris</i> .                                    |
| 1865. | 5. Des Cloiseaux, M., Prof. of Mineralogy, <i>Jardin des Plantes, Paris</i> .         |
| 1861. | 6. De Serres, M. Marcel, <i>Montpellier</i> .   |
| 1861. | 7. Deville, M. C. Ste Claire, <i>Paris</i> .  |
| 1861. | 8. Deville, M. H. Ste Claire, <i>Paris</i> .  |
| 1861. | 9. De Koninck, M. L., For. Mem. L. G. S., <i>Liège</i> .                              |
| 1861. | 10. Geinitz, M. H. B., For. Mem., L. G. S., <i>Dresden</i> .                          |
| 1863. | 11. Hunt, Dr. T. Starry, F. R. S., <i>Montreal</i> .                                  |
| 1844. | 12. Lyell, Sir Charles, F. L. S., 73, <i>Harley-street, London, W</i> .               |
| 1861. | 13. M'Clintock, Sir Leopold, R. N., 21, <i>Merrion-square, North</i> .                |
| 1852. | 14. Sedgwick, Rev. A., F. R. S., <i>Cambridge</i> .                                   |

JOURN. R. G. S. I.—VOL. III.

## HONORARY CORRESPONDING FELLOWS.

Elected.

- 1859. 1. Gordon, John, C. E., *India*.
- 1859. 2. Hargrave, Henry, J. B., C. E., *India*.
- 1859. 3. Hime, John, C. E., *Ceylon*.
- 1858. 4. Kingsmill, Thomas W., *Hong Kong*.
- 1855. 5. Medicott, Joseph, *India*.
- 1854. 6. Oldham, Thomas, F. R. S., *Calcutta*.

## FELLOWS WHO HAVE PAID LIFE COMPOSITION.

- 1853. 1. Allen, Richard Purdy, 10, *Bessboro'-terrace, North Circular Road*.
- 1861. 2. Armstrong, Andrew, 16, *D'Olier-street*.
- 1857. 3. Carson, Rev. Joseph, D. D., S. F. T. C. D., *Trinity College*.
- 1857. 4. Dowse, Richard, *Mountjoy-square*.
- 1861. 5. Fottrell, Edward, *Fleet-street*.
- 1862. 6. Frazer, W., M. D., M. R. I. A., 20, *Harcourt-street*.
- 1857. 7. Greene, John Ball, 6, *Ely-place*.
- 1848. 8. Haughton, Rev. Professor, M. D., F. R. S., 40, *Trinity College*.
- 1862. 9. Henry, F. H., *Lodge Park, Straffan, Co. Kildare*.
- 1860. 10. Hone, Nathaniel, M. R. I. A., *St. Douglough's, Co. Dublin*.
- 1861. 11. Hone Thomas, *Yapton, Monkstown, Co. Dublin*.
- 1881. 12. Hutton, Robert, F. G. S., *Putney Park, London*.
- 1867. 13. Kane, Sir R., 51, *Stephen's-green*.
- 1866. 14. Lalor, J. J., 6, *Upper Fitzwilliam-street*.
- 1856. 15. Lentaigne, John, M. D., 6, *Great Denmark-street*.
- 1851. 16. Malahide, Lord Talbot de, F. R. S., *Malahide Castle, Malahide*.
- 1867. 17. Malet, Rev. J. A., D. D., S. F. T. C. D., *Trinity College*.
- 1838. 18. Mallet, Robert, C. E., F. R. S., *The Grove, Clapham-road, London*.
- 1846. 19. Murray, B. B., *County Survey Office, Downshire-road, Newry*.
- 1859. 20. Ogilby, William, F. G. S., *Earlsfort-terrace*.
- 1852. 21. O'Kelly, Joseph, 14, *Hume-street*.
- 1849. 22. Sidney, F. J., LL. D., 19, *Herbert-street*.
- 1864. 23. Symes, Richard Glascott, 14, *Hume-street*.
- 1851. 24. Whitty, John Irvine, LL. D., 85, *Lower Mount-street*.

## FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.\*

- 1868. 1. Backhouse, M., 2, *Ontario-terrace*.
- 1854. 2. Barnes, Edward, *Ballymurtagh, Co. Wicklow*.
- 1866. 3. Bradley, Samuel, *Little Castle, Castlecomer*.
- 1832. 4. Bryce, James, LL. D., M. A., F. G. S., *High School, Glasgow*.
- 1862. 5. Carter, T. S., *Wallington Park, Wallington, Oxfordshire*.
- 1854. 6. Clemes, John.
- 1870. 7. Cooke, Samuel, C. E., *Poona, Civil Engineering College, Bombay*.
- 1857. 8. Crawford, Robert, C. E., *care of Messrs. Peto and Betts, 9, Great George's-street, Westminster, S. W.*
- 1861. 9. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee*.
- 1866. 10. Duffin, W. E. L'Estrange, *Maghera Rectory, Co. Down*.

## \* EXTRACT FROM BY-LAWS.

"Any person not residing for more than sixty-three days in each year within twenty miles of Dublin shall be a Fellow for Life, or until he comes to reside within the above distance, on paying to the Treasurers the sum of £5 5s.

"Any non-resident Life Fellow who shall reside within twenty miles of Dublin for more than sixty-three days in any one year, shall cease to be a Fellow, unless he shall either pay an additional composition of £5 5s., or shall pay a subscription of 10s. 6d. for each year in which he shall so reside for more than sixty-three days."

## Elected.

1861. 11. Dunally, Lord, *Kilboy, Nenagh.*
1832. 12. Dunraven, Earl of, F. R. S., *Adare, Co. Limerick.*
1866. 13. Ellis, R. H.
1871. 14. Emerson, Rev. J. M., *Timahoe.*
1869. 15. Enniskillen, Earl of, F. R. S., M. R. I. A., *Florence Court, Enniskillen.*
1866. 16. Graves, S. R., M. P., *Wavertree, Liverpool.*
1858. 17. Harkness, Professor, F. R. S., *Queen's College, Cork.*
1861. 18. Harte, W., C. E., *Buncrana, Donegal.*
1856. 19. Haughton, Lieut. John, R. A., *Bengal.*
1350. 20. Head, Henry, M. D., 7, *Fitzwilliam-square.*
1858. 21. Hill, J., C. E., *Ennis, Co. Clare.*
1862. 22. Hudson, R., F. R. S., F. L. S., *Clapham Common, London.*
1865. 23. Jacob, Arthur, B. A., *Bromley, Kent.*
1839. 24. James, Sir H., Colonel, R. E., F. R. S., *Ordnance Survey Office, Southampton.*
1832. 25. Kearney, Thomas, *Pallasgreen, Co. Limerick.*
1857. 26. Keane, Marcus, *Beech Park, Ennis, Co. Clare.*
1853. 27. Kinahan, George H., 28, *D'Olier-street.*
1862. 28. Kincaid, Joseph, Jun., C. E., 9, *Spring Gardens, London, S. W.*
1838. 29. Larcom, Major-General Sir Thomas, R. E., LL. D., F. R. S., *Heathfield, Fareham, Hants.*
1858. 30. Leech, Lieut.-Colonel, R. E., 3, *St. James's-square, London, S. W.*
1868. 31. Leonard, Hugh, 14, *Hume-street.*
1840. 32. Lindsay, Henry L., C. E., *Melbourne, care of J. Bower, Esq., C. E., 28, South Frederick-street.*
1867. 33. Meadows, J. M'Carthy, *Athy.*
1840. 34. Montgomery, James E., M. R. I. A.
1856. 35. Moloney, C. P., Capt., 25th Regiment, Madras N. I., *per Messrs. Grinlay and Co., 3, Cornhill, London.*
1856. 36. Medicott, Henry B., F. G. S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E. C.*
1857. 37. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, Co. Tyrone.*
1865. 38. Morton, G. H., 7, *London-road, Liverpool.*
1845. 39. Neville, John, C. E., M. R. I. A., *Dundalk.*
1870. 40. Nicholls, Thomas, 11, *Lower Gardiner-street.*
1862. 41. Nolan, Joseph, 14, *Hume-street.*
1832. 42. Renny, Henry L., R. E., *Canada.*
1870. 43. Rigby, Jason, C. E., 49, *Park-avenue, Sandymount.*
1865. 44. Scott, J. M., *Bengal Presidency College, Calcutta.*
1872. 45. Sharpe, R. W.
1868. 46. Sires, P. H., C. E.
1854. 47. Smyth, W. W., F. R. S., *Jermyn-street, London.*
1865. 48. Steele, Rev. W., *Portora Royal School, Enniskillen.*
1857. 49. Tate, Alexander, C. E., *Queen's Elms, Belfast.*
1870. 50. Taylor, J. E., F. G. S., *Bracondale, Norwich.*
1832. 51. Tighe, Right Hon. William, *Woodstock, Innistiogue.*
1866. 52. Townsend, H. W., *Clonakilty.*
1866. 53. Wall, H. P., *Portarlinton.*
1864. 54. Waller, G. A., 94, *Pembroke-road, Ball's-bridge.*
1858. 55. Webster, William B.
1871. 56. Weldon, Captain Frank.
1872. 57. White, J. N., *Waterford.*
1861. 58. Whitney, C. J., *Brisbane, Queensland.*
1846. 59. Wilson, Walter.
1864. 60. Wright, Joseph, 7, *Donegal-street, Belfast.*
1854. 61. Wyley, Andrew.
1857. 62. Wynne, Arthur B., F. G. S.

## HONORARY CORRESPONDING FELLOWS.

## Elected.

- 1859. 1. Gordon, John, C. E., *India*.
- 1859. 2. Hargrave, Henry, J. B., C. E., *India*.
- 1859. 3. Hime, John, C. E., *Ceylon*.
- 1858. 4. Kingsmill, Thomas W., *Hong Kong*.
- 1855. 5. Medicott, Joseph, *India*.
- 1854. 6. Oldham, Thomas, F. R. S., *Calcutta*.

## FELLOWS WHO HAVE PAID LIFE COMPOSITION.

- 1853. 1. Allen, Richard Purdy, 10, *Bessboro'-terrace, North Circular Road*.
- 1861. 2. Armstrong, Andrew, 16, *D'Olier-street*.
- 1857. 3. Carson, Rev. Joseph, D. D., S. F. T. C. D., *Trinity College*.
- 1857. 4. Dowse, Richard, *Mountjoy-square*.
- 1872. 5. Durham, J. S. W., *Glasthule House, Kingstown*.
- 1861. 6. Fottrell, Edward, *Fleet-street*.
- 1862. 7. Frazer, W., M. D., M. R. I. A., 20, *Harcourt-street*.
- 1857. 8. Greene, John Ball, 6, *Ely-place*.
- 1848. 9. Haughton, Rev. Professor, M. D., F. R. S., 40, *Trinity College*.
- 1862. 10. Henry, F. H., *Lodge Park, Straffan, Co. Kildare*.
- 1850. 11. Hone, Nathaniel, M. R. I. A., *St. Doulough's, Co. Dublin*.
- 1861. 12. Hone Thomas, *Yapton, Monkstown, Co. Dublin*.
- 1831. 13. Hutton, Robert, F. G. S., *Putney Park, London*.
- 1867. 14. Kane, Sir R., 51, *Stephen's-green*.
- 1866. 15. Lalor, J. J., 6, *Upper Fitzwilliam-street*.
- 1856. 16. Lentaigne, John, M. D., 6, *Great Denmark-street*.
- 1851. 17. Malahide, Lord Talbot de, F. R. S., *Malahide Castle, Malahide*.
- 1867. 18. Malet, Rev. J. A., D. D., S. F. T. C. D., *Trinity College*.
- 1838. 19. Mallet, Robert, C. E., F. R. S., *The Grove, Clapham-road, London*.
- 1846. 20. Murray, B. B., *County Survey Office, Downshire-road, Newry*.
- 1859. 21. Ogilby, William, F. G. S., *Earlsfort-terrace*.
- 1872. 22. O'Brien, William, *Ailesbury House, Merrion, Co. Dublin*.
- 1852. 23. O'Kelly, Joseph, 14, *Hume-street*.
- 1849. 24. Sidney, F. J., LL. D., 19, *Herbert-street*.
- 1864. 25. Symes, Richard Glascott, 14, *Hume-street*.
- 1851. 26. Whitty, John Irvine, LL. D., 35, *Lower Mount-street*.

## FELLOWS WHO HAVE PAID HALF LIFE COMPOSITION.\*

- 1868. 1. Backhouse, M., 2, *Ontario-terrace*.
- 1866. 2. Bradley, Samuel, *Little Castle, Castlecomer*.
- 1832. 3. Bryce, James, LL. D., M. A., F. G. S., *High School, Glasgow*.
- 1862. 4. Carter, T. S., *Wallington Park, Wallington, Oxfordshire*.
- 1854. 5. Clemes, John.
- 1870. 6. Cooke, Samuel, C. E., *Poona, Civil Engineering College, Bombay*.
- 1857. 7. Crawford, Robert, C. E., *care of Messrs. Peto and Betts, 9, Great George's-street, Westminster, S. W.*

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Elected.

1861. 8. Crosbie, William, *Ardfert Abbey, Ardfert, Tralee.*
1866. 9. Duffin, W. E. L'Estrange, *Maghera Rectory, Co. Down.*
1861. 10. Dunally, Lord, *Kilboy, Nenagh.*
1832. 11. Dunraven, Earl of, F. R. S., *Adare, Co. Limerick.*
1866. 12. Ellis, R. H.
1871. 13. Emerson, Rev. J. M., *Timahoe.*
1869. 14. Enniskillen, Earl of, F. R. S., M. R. I. A., *Florence Court, Enniskillen.*
1872. 16. Gore, J. E., *Roopur, Umballa.*
1871. 17. Hardman, E. T., 14, *Hume-street.*
1853. 18. Harkness, Professor, F. R. S., *Queen's College, Cork.*
1861. 19. Harte, W., C. E., *Buncrana, Donegal.*
1856. 20. Haughton, Lieut. John, R. A., *Bengal.*
1850. 21. Head, Henry, M. D., 7, *Fitzwilliam-square.*
1858. 22. Hill, J., C. E., *Ennis, Co. Clare.*
1862. 23. Hudson, R., F. R. S., F. L. S., *Clapham Common, London.*
1865. 24. Jacob, Arthur, B. A., *Bromley, Kent.*
1839. 25. James, Sir H., Colonel, R. E., F. R. S., *Ordnance Survey Office, Southampton.*
1832. 26. Kearney, Thomas, *Pallasgreen, Co. Limerick.*
1857. 27. Keane, Marcus, *Beech Park, Ennis, Co. Clare.*
1853. 28. Kinahan, George H., 28, *D'Olier-street.*
1862. 29. Kincaid, Joseph, Jun., C. E., 9, *Spring Gardens, London, S. W.*
1838. 30. Larcom, Major-General Sir Thomas, R. E., LL. D., F. R. S., *Heathfield, Fareham, Hants.*
1858. 31. Leech, Lieut.-Colonel, R. E., 3, *St. James's-square, London, S. W.*
1868. 32. Leonard, Hugh, 14, *Hume-street.*
1840. 33. Lindsay, Henry L., C. E., *Melbourne, care of J. Bower, Esq., C. E., 28, South Frederick-street.*
1867. 34. Meadows, J. M'Carthy, *Athy.*
1840. 35. Montgomery, James E., M. R. I. A.
1856. 36. Moloney, C. P., Capt., 25th Regiment, Madras N. I., *per Messrs. Grinlay and Co., 3, Cornhill, London.*
1856. 37. Medlicott, Henry B., F. G. S., *Geological Survey of India, per Smith and Elder, Cornhill, London, E. C.*
1857. 38. M'Ivor, Rev. James, *Rectory, Moyle, Newtownstewart, Co. Tyrone.*
1865. 39. Morton, G. H., 7, *London-road, Liverpool.*
1845. 40. Neville, John, C. E., M. R. I. A., *Dundalk.*
1870. 41. Nicholls, Thomas, 11, *Lower Gardiner-street.*
1868. 42. Nolan, Joseph, 14, *Hume-street.*
1832. 43. Renny, Henry L., R. E., *Canada.*
1870. 44. Rigby, Jason, C. E., 49, *Park-avenue, Sandymount.*
1865. 45. Scott, J. M., *Bengal Presidency College, Calcutta.*
1854. 46. Scott, R. H., *Meteorological Office, 116, Victoria-street, London.*
1872. 47. Sharpe, R. W.
1868. 48. Siree, P. H., C. E.
1854. 49. Smyth, W. W., F. R. S., *Jermyn-street, London.*
1865. 50. Steele, Rev. W., *Portora Royal School, Enniskillen.*
1871. 51. Sturman, Dr. E. A., *Queen's College, Anerley, Sydenham, London.*
1857. 52. Tate, Alexander, C. E., *Queen's Elms, Belfast.*
1870. 53. Taylor, J. E., F. G. S., *Bracondale, Norwich.*
1832. 54. Tighe, Right Hon. William, *Woodstock, Innistiogue.*
1866. 55. Townsend, H. W., *Clonakilty.*
1871. 56. Traill, William A., 14, *Hume-street.*
1866. 57. Wall, H. P., *Portarlinton.*
1864. 58. Waller, G. A., 94, *Pembroke-road, Ball's-bridge.*
1853. 59. Webster, William B.
1871. 60. Weldon, Captain Frank.

## Elected.

1872. 61. White, John N., *Waterford*.  
 1861. 62. Whitney, C. J., *Brisbane, Queensland*.  
 1846. 63. Wilson, Walter.  
 1864. 64. Wright, Joseph, 7, *Donegal-street, Belfast*.  
 1854. 65. Wyley, Andrew.  
 1857. 66. Wynne, Arthur B., F. G. S.

## FELLOWS.

1861. 1. Andrews, William, 4, *Nassau-street*.  
 1867. 2. Baily, W. H., *Hume-street*.  
 1857. 3. Bandon, Earl of, D. C. L., *Castle Bernard, Bandon, Co. Cork*.  
 1859. 4. Barker, John, M. D., 83, *Waterloo-road*.  
 1861. 5. Barrington, C. E., *Fassaroe, Bray*.  
 1862. 6. Barrington, E., *Fassaroe, Bray*.  
 1862. 7. Barton, Henry M., 4, *Foster-place*.  
 1844. 8. Bective, Earl of, *Headfort, Kells*.  
 1862. 9. Bennett, E. H., M. D., 26, *Lower Fitzwilliam-street*.  
 1872. 10. Bennett, F. J., *Jermyn-street, London*.  
 1857. 11. Bolton, George, Jun., 6, *Ely-place*.  
 1861. 12. Bolton, H. E., 6, *Ely-place*.  
 1864. 13. Bradshaw, G. B.  
 1868. 14. Brien, Charles H., *Board of Public Works, Custom-house*.  
 1870. 15. Brett, H. C., C. E., 8, *Harrington-street*.  
 1872. 16. Budds, Rev. Thomas, *Blackrock, Co. Dublin*.  
 1857. 17. Carte, Alexander, M. D., F. L. S., *Royal Dublin Society*.  
 1867. 18. Clarke, G. R., *Public Works Department, Lucknow, India*.  
 1862. 19. Close, Rev. Maxwell, *Newtown Park, Blackrock*.  
 1858. 20. Cotton, Charles, P., C. E., 11, *Lower Pembroke-street*.  
 1862. 21. Cousins, A. L., C. E.  
 1863. 22. Crook, Rev. R., LL. D., *Wesleyan College, Belfast*.  
 1868. 23. Cruise, R. J., 14, *Hume-street*.  
 1853. 25. De Vesci, Lord, *Abbeyleix House, Abbeyleix*.  
 1849. 26. Downing, Samuel, LL. D., C. E., *Trinity College*.  
 1852. 27. Doyle, J. B., *Derrymore House, Newry*.  
 1867. 28. Dunscombe, Clement, *King William's Town, Co. Cork*.  
 1872. 33. Egan, F. W., 1, *Castleblayney*.  
 1865. 29. Fleming, John M., *Alderney, Channel Islands*.  
 1866. 30. Foot, A. W., M. D., 21, *Lower Pembroke-street*.  
 1867. 31. Forster, R., *University Club*.  
 1858. 32. Gages, Alphonse, M. R. I. A., 51, *Stephen's-green*.  
 1849. 34. Galbraith, Rev. Joseph A., F. T. C. D., *Trinity College*.  
 1865. 35. Gibson, John, C. E., *Stapleton-place, Dundalk*.  
 1867. 36. Gore, J. E., C. E.  
 1865. 37. Gray, R. A., C. E., 5, *Palmerstown Villas, Upper Rathmines*.  
 1859. 38. Green, Murdock, 52, *Lower Sackville-street*.  
 1862. 40. Gribbon, C. P., 72, *Stephen's-green*.  
 1831. 41. Griffith, Sir R., Bart., LL. D., F. G. S., 2, *Upper Fitzwilliam-place*.  
 1857. 42. Hampton, Thomas, C. E., 6, *Ely-place*.  
 1866. 43. Heron, Robert, *Harrow House, Ballybrack*.  
 1861. 44. Hudson, A., M. D., *Merrion-square*.  
 1870. 45. Hull, Edward, M. A., F. R. S., 14, *Hume-street*.  
 1865. 46. Hutton, T. M., 118, *Summer-hill*.  
 1852. 47. Jellett, Rev. J., F. T. C. D., M. R. I. A., 9, *Trinity College*.  
 1842. 48. Jennings, F. M., M. R. I. A., *Brown-street, Cork*.  
 1871. 49. Kelly, G. N. H., *Fair-street, Drogheda*.  
 1862. 50. Kinahan, G., J. P., *Roebuck-hill, Dundrum*.  
 1866. 51. Knapp, W. H., C. E., 5, *Summerhill-road, Kingstown*.  
 1865. 52. Leech, John, C. E., 6, *Ely-place*.

## Elected.

1831. 53. Lloyd, Rev. Humphrey, D. D., F. R. S., Provost, T. C. D., *Provost's House*.  
 1863. 54. Macalister, A., M. B., 19, *Leinster-road, Rathmines*.  
 1855. 55. M'Cauland, Dominick, 12, *Fitzgibbon-street*.  
 1861. 56. M'Comas, A., *Cliff Castle, Dalkey*.  
 1863. 57. M'Donnell, Alexander, C. E., *St. John's, Inchicore*.  
 1851. 58. M'Donnell, John, M. D., 4, *Gardiner's-row*.  
 1837. 59. Mollan, John, M. D., 8, *Fitzwilliam-square*.  
 1859. 60. Moore, Joseph Scott, J. P., *Hume-street*.  
 1831. 61. Nicholson, John, M. R. I. A., *Balrath House, Kells*.  
 1856. 62. O'Brien, Octavius, 23, *Kildare-street*.  
 1871. 63. O'Leary, W. H., M. D., *York-street Dublin*.  
 1865. 64. Ollis, G., *The Camp, Aldershot*.  
 1864. 65. Palmer, Sandford, *Roscrea*.  
 1857. 66. Porter, William, C. E., *Leinster Club, Clare-street*.  
 1865. 67. Radley, John, *Gresham Hotel, Sackville-street*.  
 1864. 68. Reynolds, J. Emerson, M. D., *Royal Dublin Society*.  
 1857. 69. Reeves, R. S., 22, *Upper Mount-street*.  
 1861. 70. Roberts, W. G., *Nenagh, Co. Tipperary*.  
 1862. 71. Rowan, D. J., O. E., *Athlone*.  
 1864. 72. Russell, H.  
 1852. 73. Smith, Robert, M. D., 63, *Eccles-street*.  
 1866. 74. Stewart, H., M. D., *Lucan*.  
 1859. 75. Stokes, William, M. D., F. R. S., 5, *Merrion-square, N*.  
 1861. 76. Stoney, Bindon, C. E., 42, *Wellington-road*.  
 1852. 77. Taylor, Colonel Meadows, M. R. I. A., *Oldcourt, Harold's-cross*.  
 1864. 78. Tichborne, C. R. C., *Apothecaries' Hall, Mary-street*.  
 1869. 79. Traquair, R. H., M. D., 51, *Stephen's-green*.  
 1859. 80. Waldron, L., LL.D., *Ballybrack*.  
 1863. 81. Westropp, W. H. S., M. R. I. A., *Lisdoonvarna, Co. Clare*.  
 1872. 82. Wilkinson, Sydney B., 14, *Hume-street*.  
 1863. 83. Williams, Richard Palmer, 38, *Dame-street*.  
 1872. 84. White, H. V., C. E., *Borough Surveyor's Office, Kingston-on-Thames, S. W*.  
 1851. 85. Wright, Edmund P., LL.D., M. R. I. A., 5, *Trinity College, Dublin*.  
 1871. 86. Wright, Edward P., M. D., 5, *Trinity College*.

## No. II.

## LIST OF MEMBERS ELECTED IN 1872.

1. John N. White.
2. Frederick William Egan.
3. Henry V. White.
4. Thomas Budda.
5. F. J. Bennett.
6. J. S. W. Durham.
7. Sydney B. Wilkinson.
8. Francis Coffey.

## No. III.

## State of the Society:—

	Last Report.	Present Year.
Honorary Fellows, . . . .	14 . . . .	13
Corresponding do., . . . .	6 . . . .	6
Life do., . . . .	87 . . . .	91
Annual, do., . . . .	89 . . . .	86
	196	196

No. IV.

SOCIETIES AND INSTITUTIONS TO WHICH THE JOURNAL OF THE  
ROYAL GEOLOGICAL SOCIETY OF IRELAND IS SENT.

ABERDEEN, . .	University Library.
ALBANY, . . .	State Library, New York.
AMSTERDAM, .	Royal Academy of Sciences.
ANTWERP, . .	Société Paléontologique de Belgique.
BELFAST, . .	Queen's College Library.
	Naturalists' Field Club.
BERLIN, . . .	Royal Academy of Sciences.
	German Geographical Society.
	German Geological Society, per Bessersche Buchhandlung, <i>Behren-</i> <i>str., 7, Berlin.</i>
BOLOGNA, . .	Accademia delle Scienze delle Istituto.
BORDEAUX, . .	Imperial Academy of Sciences.
BOSTON, . . .	American Academy.
	Natural History Society.
BRISTOL, . . .	Institution for the Advancement of Science, Literature, and the Arts.
BRÜNN, . . .	Naturforschende Verein.
BRUSSELS, . .	Academy of Sciences.
CAEN, . . .	Société Linnéenne Normandie.
CALCUTTA, . .	Asiatic Society.
	Public Library.
	Geological Survey of India.
CAMBRIDGE, .	Philosophical Society.
	Trinity College Library.
CANTERBURY, .	} Geological Survey.
NEW ZEALAND, .	
COPENHAGEN, .	Royal Society of Science.
CORK, . . .	Queen's College, Library.
	Royal Institution.
DIJON, . . .	Academy of Sciences.
DRESDEN, . .	The "Isis" Society.
DUBLIN, . . .	Royal College of Surgeons' Library.
	Royal Irish Academy.
	University Library.
	Royal Dublin Society.
	Natural History Society.
	Ordnance Survey Library.
	Professor Sullivan, as Editor of the "Atlantis."
	Geological Survey of Ireland.
	Institution of Civil Engineers.
EDINBURGH, .	Royal Society.
	Royal Scottish Society of Arts.
	University Library.
	Society of Antiquaries.
	Advocates' Library.
FALMOUTH, . .	Royal Cornwall Polytechnic Society.
FLORENCE, . .	Society of Physics and Natural History.
GALWAY, . . .	Queen's College Library.
GENOA, . . .	Society of Physics.
GLASGOW, . .	University.
	Geological Society.
GÖTTINGEN, .	University.
HAARLEM, . .	Société Hollandaise des Sciences, per B. Quarritsch, 15, <i>Piccadilly,</i> <i>London.</i>
HALLE, . . .	Naturwissenschaftliche Verein für Sachsen und Thüringen, per An- tons Buchandlung, <i>Halle.</i>

- HANAU, . . . Oberhessische Gesellschaft der Natur-und Heil-kunde.  
 HANOVER, . . . Royal Library.  
 KILKENNY, . . . Archæological Society.  
 KÖNIGSBERG, . . . Königlich Physicalisch-Oekonomische Gesellschaft.  
 LAUSANNE, . . . Société Vaudois des Sciences Naturelles.  
 LEEDS, . . . Geological and Polytechnic Society of the West Riding of Yorkshire.  
 LEIPSIC, . . . Philosophical and Literary Society.  
 . . . Royal Society of Sciences (Saxony).  
 . . . University.  
 LIVERPOOL, . . . The Literary and Philosophical Society.  
 . . . Historical Society of Lancashire and Cheshire.  
 . . . Geological Society, The Royal Institution, *Colquitt-street*.  
 LONDON, . . . Geological Survey, *Jermyn-street*.  
 . . . British Museum.  
 . . . Society of Arts, *John-street, Adelphi*.  
 . . . Royal Institution, *Albemarle-street*.  
 . . . Royal Society, *Burlington House*.  
 . . . Geological Society, *Somerset House*.  
 . . . Linnean Society, *Burlington House*.  
 . . . Royal Geographical Society, 15, *Whitehall-place*.  
 . . . Civil Engineers, Institution of, 25, *Great George's-street, Westminster*.  
 . . . Royal Asiatic Society, 5, *New Burlington-street*.  
 . . . Royal College of Surgeons, *Lincoln's Inn*.  
 . . . Zoological Society, 11, *Hanover-square*.  
 . . . Athenæum, 14, *Wellington-street, Strand, London, W. C.*  
 . . . Anthropological Society, 4, *St. Martin's-place, London, W. C.*  
 LYONS, . . . La Société Impériale d'Agriculture, d'Histoire Naturelle, et des  
 . . . Arts Utiles.  
 . . . Société Linnéene.  
 . . . Académie Impériale, per Treuttel & Wurtz, 19, *Rue de Lille, Paris*.  
 MADRID, . . . Academia de Ciencias.  
 MANCHESTER, . . . Literary and Philosophical Society of. [See R. C. Christie].  
 . . . Geological Society.  
 MELBOURNE, . . . Philosophical Institute of Victoria.  
 . . . The Public Library, per Bain and Co., 1, *Haymarket, London*.  
 . . . The Royal Society.  
 MILAN, . . . Reale Istituto Lombardo di Scienze.  
 MISSOURI, . . . State Survey and University, *Geological Rooms, Columbia, U. S. A.*  
 MODENA, . . . Institute of Science.  
 MONTREAL, . . . Natural History Society.  
 MUNICH, . . . Royal Academy of Science (2 copies).  
 NEUCHÂTEL, . . . Société des Sciences Naturelles.  
 NEW HAVEN, . . . } The Editors of Silliman's Journal of Science and Art.  
 U. S. A., }  
 NEW YORK, . . . Lyceum of Natural History.  
 OXFORD, . . . Bodleian Library.  
 . . . Ashmolean Society.  
 PALERMO, . . . Accademia di Scienze e Lettere.  
 PARIS, . . . Ecole Polytechnique.  
 . . . Geological Society.  
 . . . L'Ecole Impériale des Mines.  
 . . . Institute of France.  
 . . . Bibliothèque Impériale.  
 . . . Jardin des Plantes, Bibliothèque.  
 PHILADELPHIA, . . . American Philosophical Society.  
 . . . Academy of Natural Sciences, per Trübner and Co.  
 PLYMOUTH, . . . The Plymouth Institution and Devon and Cornwall Natural History  
 . . . Society.  
 PRESBURG, . . . Der Verein für Naturkunde.  
 QUEBEC, . . . Literary and Historical Society.  
 ROME, . . . The Vatican Library.  
 ROUEN, . . . Academy of Sciences.  
 ST. ANDREWS, . . . University Library.

- ST. LOUIS, . . Academy of Sciences.  
 ST. PETERSBURG Imperial Academy.  
                     Central Physical Observatory of Russia.  
                     Russisch-Kaiserliche Mineralogische Gesellschaft.  
 STOCKHOLM, . Royal Academy of Science, per Longman and Co., *Paternoster-row,*  
                     *London*; and Sampson and Wallis, *Stockholm.*  
                     Geological Survey of Sweden.  
 STRASBURG, . Société des Sciences Naturelles.  
 STUTTGART, . Verein für vaterländische Naturkunde.  
 TORONTO, C.W., Canadian Institute, per Thomas Henning, Esq.  
 TOULOUSE, . Academy of Sciences.  
 TRURO, . . . Royal Institute of Cornwall.  
 TURIN, . . . Royal Academy.  
 UPPSALA, . . Royal Society of Sciences.  
 VIENNA, . . Imperial Academy of Sciences.  
                     Prof. W. Haidinger, of Vienna, as Editor of the "Jahrbuch der K.  
                     K. Geologischen Reichsanstalt."  
                     K. K. Zoologisch-botanische Gesellschaft, per Braumüller and Co.,  
                     *Vienna.*  
 WASHINGTON, Smithsonian Institute Library, per W. Weale, Esq., 28, *Essex-street,*  
                     *Strand, London.*  
 WINDSOR, . . The Royal Library.  
 ZURICH, . . . Naturforschende Gesellschaft.

# No. V.—ROYAL GEOLOGICAL SOCIETY OF IRELAND.

*Abstract of Treasurer's Account for the Year ended 31st December, 1872.*

1872.	Dr.	£	s.	d.	1872.	Cr.	£	s.	d.
1872.	To Balance in Royal Bank, to 31st December, 1871,	24	5	5	March 7.	By paid Collector, Poundage for 1871,	£10	10	0
	" Life Compositions to 31st December, 1872,				" "	" Life Composition of S. W. Durham,	10	10	0
	" Entrance Subscriptions to do.,				" "	" do. W. O'Brien,			
	" Annual Subscriptions to do.,	103	9	6	" "	" Stock purchased,	£23	0	6
Feb. 3.	Received from Dr. Macalister (sale of books)	4	0	0	Feb. 16.	" do. W. A. Trail, Stock,	5	12	4
	" Received dividends on £330 13s. 8d., to 5th April, 1872,	4	16	8	March 7.	" Cassel, Pettor, and Galpin, for 800 Maps,			
	" do. on £353 14s. 2d., to 5th Oct., 1872,	5	4	4	March 7.	" Dr. Haughton, Petty Expenses,			
					" "	" Dr. Haughton, Petty Expenses,			
					" "	" Mr. A. H. Ormsby, one Quarter's Salary, to 31st March,			
					May 1.	" Mr. W. H. Bailly, for Drawing on Stone for Journal,	£2	0	0
					June 5.	" Connor's Wages for April and May,	1	15	0
					" "	" Cook, and for Coals,			
					" "	" Connor, for June, July, and August,	£3	0	0
					" 19.	" Mr. A. H. Ormsby to 30th June,	2	10	0
					" "	" Dr. Haughton, Petty Expenses,			
					Nov. 6.	" Mr. A. H. Ormsby, to 30th September,	£2	10	0
1873.					" "	" Connor, for September and October,	2	0	0
					Dec. 4.	" Mr. A. H. Ormsby, to 31st December,	£2	10	0
					" "	" Connor, for November and December,	2	0	0
					" "	" Dr. Haughton, Petty Expenses,			
					1873.	" Sundries, Mrs. Connor, Coals, &c.,	£1	16	3
					Jan. 2.	" do. Williams and Norgate,	0	17	6
					" "	" Mintern, Brothers, Lithographers,			
					Feb. 5.	" Life Composition of H. N. White,	£5	5	0
					" "	" do. Robert H. Sharpe,	5	5	0
					" "	" do. J. E. Gore,	5	5	0
					" "	" Stock purchased,	£17	0	5
					" "	" Collector, poundage for 1872,	4	15	0
Feb. 3.					" "	" do. Postage, 3s., Circulars, 4s., 6d.,	0	7	6
					" "	" Bank Cheque Book,			
					" "	" Balance in Collector's hands,	£8	2	0
					" "	" do. in Bank,	28	18	8
Total,		£141 15 11				Total,	£141 15 11		

February 11th, 1873.

Examined, compared with Vouchers, and found correct.

EDWARD HULL.



# JOURNAL

OF THE

## ROYAL GEOLOGICAL SOCIETY OF IRELAND.

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### I.—REPORT OF COUNCIL FOR 1870-71.

[Read February 8, 1871.]

YOUR Council in resigning their charge into the hands of the Society have great pleasure in reporting the continued prosperity of the interests committed to their care during the year that is past. The eventful year 1870 has brought no changes of importance in the affairs of the Society, which, in a pecuniary and scientific point of view, have never been in a more flourishing condition.

The attendances at the meetings have been much larger than during the preceding years, and the interest evinced by the Fellows in the proceedings has been steadily increasing.

Three of the evening meetings have been held by our society conjointly with the Royal Zoological Society, and at these, papers on subjects of general natural history have been read. Such of these papers as referred to zoological subjects have been printed and published in the "Annals of Natural History" and those purely geological are in course of publication in the forthcoming part of our Journal, which your Council hope, will soon be ready for circulation.

Death has been busy in our ranks during the past year, and we have to deplore the loss of four Fellows—A. H. Haliday, the Hon. James King, the Rev. Thomas Luby, S.F.T.C.D., and Mr. H. Ormsby, LL.D. Mr. Halliday was a Fellow of the Society for many years, and one who took a warm interest in all branches of Natural Science, although he devoted his attention chiefly to entomology, in connexion with which science his name is so well known, not only in this but in all civilized countries. The Hon. James King and the Rev. Dr. Luby were Fellows of the Society who also took an interest in its affairs, although their other avocations prevented them from taking any actual part in its management.

It is with the most heartfelt regret that your Council have to record the sudden death of Dr. Montague H. Ormsby, of the Geological Survey of India, at the early age of 28. Not more than a year ago he held a seat in the Council of this Society, and, by his geniality and his devotion to geological science, he not only made himself personally beloved by those with whom he was associated, but also gave promise of becoming one of the foremost in the ranks of geological workers. He was engaged in making great and valuable researches on the mineralogy of the igneous and metamorphic rocks of India when he was struck down by the hand of death. Several papers of his have been published in the Journal of this Society, the most important of which is one on a new mineral which he discovered at Enniskerry.

We have gained four new Fellows during the past year.

The papers which have been read at our meetings have been of very great interest, and have mainly dealt with subjects of physical geology. Mr. Whitty brought before our notice many interesting points regarding the Structure of the Granites of Lundy Island. The Rev. Professor Haughton has drawn the attention of the Society to the Probable Geological Effects of the permanent Opening of the Suez and Darien Canals, and also to the Horizontal Thrust produced by the Secular Cooling of the Earth, and its Effects in producing Continents and Seas. The Rev. Maxwell Close, who has brought before the Society from time to time so many valuable papers on the Glaciation of Ireland, has brought before us the Phenomena of Corries and their Rock Basins, as exemplified in the County Kerry. Mr. Kinahan has read before us an interesting series of Notes on Metamorphic Rocks. Mr. Hull, Director of the Geological Survey, has given to us the results of his investigations in the Geological Age of the Ballycastle Coalfield, County Antrim; and the phenomenon of the Moving bog of Castlereagh was the subject of a paper by Mr. Leech.

On mineralogy the papers read were, first, on the Mineral Constituents of the Granites of Scotland, by the Rev. Professor Haughton; and on a Perforated Crystal of Galena, by Dr. J. Emerson Reynolds, V. P. Dr. Reynolds also brought before the Society a new method of exhibiting minerals by the lime light.

An interesting communication was read before us by Professor Traquair on the scales of the rare African ganoid fish *Calamoichthys*; and Dr. Frazer exhibited a series of Ancient Irish Mining Implements from Queen's County.

An interesting series of rocks and minerals from Sicily were also exhibited at one of our evening meetings, presented by Professor Guiscardi and R. Mallet, Esq., and a collection of fossil plants from Canada, by Principal Dawson.

II.—ON TWO REMARKABLE CRYSTALS OF GALENA. By J. E. EMERSON REYNOLDS, M. R. C. P., Keeper of Mineral Department and Analyst, Royal Dublin Society.

[Read April, 1870.]

THE crystals of galena which I have the pleasure of submitting to the Society possess some interest as being specimens of a mineral usually found to occur in some form belonging to the monometric system, but in the present instance appearing to crystallize in a very different manner.

I may first describe the specimens, and then endeavour to account for the peculiar mode of occurrence of the mineral.

The galena crystals are two in number, and are imbedded in a coarsely crystallized mass of white, translucent, rhombohedral calc-spar.\* The larger of the two crystals was exposed throughout its length, a plate of the matrix having been carefully removed. The length of the crystal is 14 millimetres, and the greatest breadth, 4.2 millimetres. The crystal is a very well-defined six-sided prism, slightly curved in the direction of the major axis. The vertical planes of the prism are seen to be rather unequally developed; but the interfacial angles being somewhat rounded, I was unable to determine their value with precision; they were, however, approximately those of the regular hexagon. The crystal is terminated each way by a brilliant cleavage plane—the inclination of the latter to the major axis approached  $124^\circ$ , but the situation of the crystal and its curvature rendered accurate measurement of the angle impossible. The crystal is centrally pierced in the direction of its length by a fine thread-like core of sub-crystalline calc-spar.

The second specimen of galena is about half the size of that last described, and is much less perfect, though very similar in form. It is broken in such a way that the calc-spar core, likewise present in this instance, is laid bare, and can be traced throughout the length of the crystal.

The mode of occurrence, very marked form, and existence of a core of carbonate of calcium in each crystal, give probability to the view that the galena has in each case replaced a hexagonal prism of calc-spar. Each crystal may then be regarded as a galena pseudomorph after calc-spar, in which the replacing mineral not only assumes the shape, but likewise, as we have seen, simulates the cleavage of the body replaced. The chemical changes involved in the production of these

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\* The specimen was obtained on the banks of the Grand Canal, near Tullamore, King's County, by the late Mr. Wright, of Cork.

pseudomorphs need no special notice here, but I may be allowed to refer to one or two points suggested by the careful examination of the little galena crystals.

It is well known that the prevailing form of galena is that of a more or less modified cube; but specimens of the mineral have been obtained in which the rhombic dodecahedron of the system predominated. Galena, therefore, can occur in nature in the latter form. A hexagonal prism of calc-spar, with rhombohedral terminations, is a dodecahedron likewise, in which the vertical axis may be assumed to connect the two trifacial angles. If the rhombic dodecahedron of the monometric system be placed in a similar position, i. e. with one of the trifacial angles uppermost, it will be seen to differ from the analogous form of the hexagonal system chiefly in the matter of constant proportional length of the prism. Galena and this particular variety of calc-spar must, therefore, be regarded as bodies very closely allied in form, the rhombic dodecahedron of one mineral being capable of readily taking the place of the corresponding form of the other, simply by extension in one direction.

Again, the prismatic calc-spar crystals always exhibit the well-known rhombohedral cleavage of the mineral. The galena pseudomorph, as already stated, simulates this peculiarity of structure likewise. But the observed cleavage planes of the pseudomorph really correspond to, and no doubt represent, the cubical cleavage planes of a true rhombic dodecahedron of galena.

It would appear, then, that the galena crystals described in this note are distorted rhombic dodecahedrons of the mineral, retaining the normal cleavage;\* and that this distortion of each crystal in one direction has been the result of the attempt of the galena not only to imitate the shape of the prismatic calc-spar which it has replaced in the specimen, but at the same time to satisfy its own peculiar mode of molecular aggregation.

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\* Crystals of garnet are well known to be frequently distorted in the same manner, though not to the same extent, as the galena crystals. Many artificially prepared salts exhibit the same tendency, notably the cupri-potassic chloride.

III.—ADDITIONAL NOTES ON FOLIATION. By G. H. KINAHAN,  
M. R. I. A., &c.

[Read February 8, 1871.]

SOME time since I pointed out that the foliation in metamorphosed sedimentary rocks always, *at the first*, followed the most conspicuous structure in the original rocks.\* Perhaps I now may be allowed to lay before the members of the Society additional notes on foliation.

All metamorphosed rocks, whether originally they were "derivate" (sedimentary) or igneous, may occur in different degrees of change—from an almost normal, scarcely altered rock, to a rock so granitoid as to be hardly distinguishable from granite, into which they graduate—this being due to the intensity of the metamorphic action.

When metamorphism first begins in derivate rocks, they become indurated, certain minerals, such as chialstolite, phyllite, pyrite, and the like being developed; while the planes of the most conspicuous structure [let it be lamination, cleavage, or jointing] become glazed or micacised. Moreover, peculiar structures are often observable—in finely laminated or cleaved rocks, a crumpled or frilled-like structure; in other rocks there is a nodular or concretionary development; while in some, the joint lines, or the rock in the immediate vicinity of the joint lines, becomes silicified or hardened; so that weathered surfaces of the rock show more or less regular rectangular, rhombic or oblique figures, divided from one another by well marked walls, from mere lines to two or three inches thick (Fig. No. 1). Eventually the rocks become typical schist, from which they merge into gneiss, and after gradually becoming more and more granitoid, they change into granite.

In all the above stages, except the transition between gneiss and granite, the foliation follows the most marked structure in the original rock, let it be jointing, cleavage, or lamination; whether the latter was parallel, oblique, spheroidal, concretionary, curled, or nodular. As, however, the rocks become granitoid, the original structure is obliterated, and the foliation becomes more and more regular,

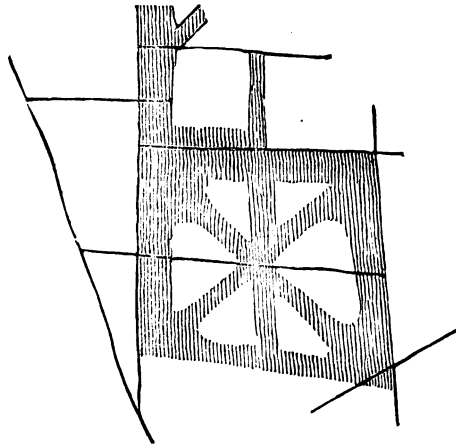


Fig. No. 1.

\* Dublin Quarterly Journal of Science, vol. vi. p. 185.

in parallel lines, also perpendicular, or nearly so. Nevertheless, a few varieties of rock, such as conglomeritic and nodular rock, appear able, more or less, to partially resist this change in the foliation; for in many rocks originally conglomerates, even when the mass is so granitoid as to be nearly undistinguishable from a granite, portions of the foliation will be deflected or curled in the vicinity of enclosed blocks or nodules; so that, even in some intrusive oligoclasic granites, nodules, often irregular in shape, and always differing in constituents from the mass of the rock, will be found (Fig. No. 2).\*

The regular changes to which these rocks are subjected will appear from what has been said:—*First*, to become schist; *second*, gneiss; *third*, granite.

There are, however, exceptions to this general rule, as some derivate rocks are more susceptible of change than others, on account of their constituents, while in some all the ingredient of gneiss will occur; consequently, in the *schist-series*, beds of gneiss will be found; and in the *gneiss-series* beds of schist, even when the associated beds are very granitoid.†

The changes in the igneous rocks do not appear to be as regular as those in the metamorphic derivate rocks. At the first, if there is a conspicuous structure in the original rock, (such as a platy arrangement rudely parallel to the walls of the dykes, an oblique platy structure, a spheroidal structure, a concretionary or nodular development, cleavage, or fine jointing) the surfaces may be micacised and a foliation induced; many igneous rocks, however, are more or less homogeneous, especially many of the basic-rocks, and in them foliation is rarely, if ever, developed. The most common foliation in the metamorphosed igneous rocks is more or less parallel to the walls of the dykes, nevertheless an oblique foliation is not uncommon (Fig. No. 3), and near the termination of dykes a spheroidal foliation.

As in the derivate rocks, so in the igneous rocks; when the changes are regular, the rocks first become schistose, second gneissose, and lastly granite. The homogeneous rocks become more and more crystalline, until

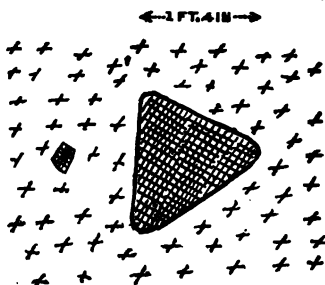


Fig. No. 2.

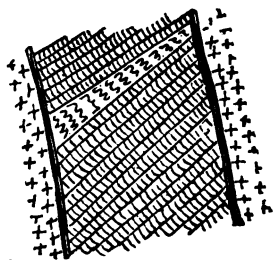


Fig. No. 3.

\* Perhaps I may be allowed to suggest that, hereafter, Microscopists may prove that these granitoid gneisses ought properly to be classed with granitic rocks, as *Foliated granite*; for, besides losing their original structure, they appear to be completely crystallized rocks.

† Mem. Geol. Survey, Ireland, Ex. sheet 105, p. 34. When a derivate-rock contains the constituents of gneiss, the metamorphic rock rarely at the first becomes a typical gneiss, (leaves of quartz, felspar, and mica), the minerals occurring jumbled and mixed up together.

at last they graduate into granite. In felstone and such rocks, minerals, such as mica, amphibole, and ripidolite, are developed in the first stage: while in the second the felsitic mass is developed into quartz and felspar. In basic rocks, amphibole, ripidolite and mica, are first developed, and lastly quartz.

The acid and "hybrid rocks" (according to Durocher's classification), when metamorphosed, appear to be more often foliated than the metamorphic basic rocks.

There is, however, in some rocks a foliation hard to be accounted for. Instances of this are dykes of gneiss and schist in porphyritic-oligoclasic granite, at Barna, County Galway, and veins or dykes of foliated porphyritic granite in schist and gneiss, to the N. E. of Castlebar, County Mayo.\*

If foliation is solely due to metamorphism, the following suggestions might perhaps account for it in these dykes or veins. At Barna, the dykes evidently did not exist until after the rocks, which are now granite, were metamorphosed. Nevertheless, they might have been intruded while these rocks were in the granitoid-gneiss stage, and prior to their becoming granite; consequently, while the granitoid-gneiss was being altered into granite, the dykes would be altered into gneiss and schist. The foliated granite in dykes N.E. of Castlebar might, perhaps, similarly be accounted for. It is an established fact, that the sedimentary rocks in the vicinity of some masses of intruded granite are so slightly changed as to be scarcely distinguishable from the unaltered sedimentary rocks in their vicinity, even although they are intersected and cut by veins of granite. This is well exemplified in the Dartmoor granite, Devonshire. Might not such have once been the case to the N. E. of Castlebar; and when the granite was first intruded, the adjoining sedimentary rock may have been scarcely changed? If, subsequently, a more intense action set in, the sedimentary rocks would be altered into schist and gneiss, while a foliation would be introduced into the granite.

The second suggestion seems more probable than the first, but to me neither of them is satisfactory; moreover, it is not yet clear but that in some dykes of igneous rocks there may be a foliation, not due to ordinary metamorphic action. In one locality massive dykes of more or less granitoid gneiss, that seem to proceed from a mass of intrusive granite, were observed. Yet the associated sedimentary rocks are so little altered as barely to entitle them to be considered as metamorphic rocks. That these rocks should be good gneiss while the associated sedimentary rocks are scarcely altered appears remarkable, and as yet a solution of the anomaly has not suggested itself to me.

The following table gives the changes in the rocks as they seem to occur:—

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\* Memoirs Geological Survey of Ireland, Ex. sheet 105, p. 80, and Ex. Sheets 104, 118, &c., pp. 18 and 19.

TABLE OF CHANGE IN ROCKS.

Original Rock.	First Change.	Second Change.	Final Product.
Felspathic and mica- ceous sandstone, are- naceous shale or slate	Gneiss, *. . . .	Gneiss, . . . .	Granite.
Quartzitic sandstone or grit,	Quartzite, or quartz schist. Quartzitic mica schist,	Gneiss, . . . .	Granite.
Argillaceous shale or slate,	Argillyte, Mica schist,	Gneiss, . . . .	Granite.
Greenish tuffose shale or slate,	Chloritic mica schist, Hornblendic schist, Chloritic schist, Talcose schist,	Basic gneiss, . .	Oligoclasic granite, often hornblendic, sometimes titani- tic.
Basic tuff, . . . .	Hornblende schist, Chlorite schist, Talc schist,	Basic gneiss, . .	Oligoclasic granite, often hornblendic, sometimes titani- tic.
Felsitic tuff, † . . .	Felsite schist, Steatitic schist, Talcose schist, Garnetiferous schist, Steatyte,		
Diabase, . . . .	Hornblendic schist, Aphanyte,	Dioryte, † Syenyte, Hornblende rock, Hyperyte,	Oligoclasic granite, sometimes horn- blendic or chlori- tic, &c.
Euryte, ‡ . . . .	Hornblendic felstone, Chloritic felstone, Hornblendic felsitic schist,	Basic gneiss, . .	Oligoclasic granite.
Scaly or flaky fel- stone,	Felsitic schist, Steatitic schist, Talcose schist, Steatyte,		
Felstone, . . . .	Felsite schist, Felsitic mica schist,	Gneiss, . . . .	Granite.
Petro-silex (Homo- geneous felstone),	A compound of felsite and mica, or of fel- site, mica and quartz.	Gneiss, § . . . .	Granite.

\* This gneiss is not typical; the quartz, felspar, and mica, not being arranged in leaves. The gneiss and granite of this and the two next following, may be very varied in character according to the constituents varying in the original rocks.

† The second changes of these rocks were not observed—the *scaly felstones* are very tuffose in appearance, but seem always to occur in intrusive masses.

‡ *Dioryte*; amphibole and felspar (not orthoclase)—*Syenyte*; amphibole and orthoclase, quartz often present, but not an essential mineral.

‡ The original *Eurytes* or *Eurites* of Daubuisson (*basic felstones*).

§ *Gneiss* from *Petrosilex* is rarely typical, the minerals being mixed up together; and some of the *silex* not being separated, but in combination with the felspar, and forming a felsitic substance.

IV.—SUPPLEMENTARY NOTES ON SOME OF THE DRIFT IN IRELAND. By  
G. HENRY KINAHAN, M. R. I. A., &c., &c.

[Read April 12, 1871].

In a former paper read before the Society [*“Notes on some of the Drift in Ireland.”* *Dublin Quarterly Journal of Science*, Vol. VI. p. 249, a review as to the causes for the formation of some kinds of the drift was attempted; moreover, it was suggested from the facts therein stated, that one drift, which may be called the *Boulder clay drift*, was perhaps partly of marine origin, while another division, the *Boulder or Moraine drift* was glacial, and that the *Esker drift* or *Post drift gravels* was formed by the tidal currents. Since then a paper has been published by J. W. Dawson, LL.D., F.R.S., Principal of McGill College, *“On Comparison between the Glaciers of Mount Blanc and the Icebergs of Belleisle,”*\* in which this eminent observer has put forward views in regard to the classification and formation of these drifts. As Doctor Dawson has drawn up his conclusions in a tabular form, perhaps it may be allowable to quote as follows his comparisons between the work capable of being done by floating ice, and that done by glaciers:—

“1st. Glaciers heap up their debris in abrupt ridges. Floating ice sometimes does this, but more usually spreads its load in a more or less uniform sheet.

“2nd. The material of moraines is all local. Icebergs carry their deposits to great distances from their sources.

“3rd. The stones carried by glaciers are mostly angular, except they have been acted on by torrents. Those moved by floating ice are more often rounded, being acted on by the waves, and by the abrading action of sand drifted by currents.

“4th. In the marine deposits, mud is mixed with stones and boulders. In the case of glaciers most of this mud is carried off by streams and deposited elsewhere.

“5th. The deposits from floating ice may contain marine shells. Those of glaciers cannot, except where, as in Greenland and Spitzbergen, glaciers push their moraines out to sea.

“6th. It is of the nature of glaciers to flow in the deepest ravines they can find, and such ravines drain the ice of extensive area of mountain land. Icebergs, on the contrary, act with greatest ease on flat surfaces or slight elevations in the sea bottom.

“7th. Glaciers must descend slopes, and must be backed by large supplies of perennial snow. Icebergs act independently, and being water-borne may work up slopes and on level surfaces.

“8th. Glaciers striate the sides and bottoms of their ravines very unequally, acting with great force and effect only on those places where

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\* *“Canadian Naturalist and Geologist,”* New Series, vol. iii., No. 1.

their weight impinges most heavily. Icebergs, on the contrary, being carried by currents, and over comparatively flat surfaces, must striate and grind more regularly over large areas, and with less reference to local inequalities of surfaces.

"9th. The direction of the striæ and grooves produced by glaciers depends on the direction of valleys. That of icebergs, on the contrary, depends upon the direction of marine currents, which is not determined by the outlines of the surface, but is influenced by the large and wide depressions of the sea bottoms.

"10th. When subsidence of the land is in progress, floating ice may carry boulders from lower to higher levels. Glaciers cannot do this under any circumstances, though in their progress they may leave blocks perched on the tops of peaks and ridges."

It may be observed that Principal Dawson's suggestions for the rounding of blocks in the *debris* left by icebergs, in his third comparison, would seem to be scarcely correct, for blocks rolled about by currents, and abraded by drifted sand, ought to lose all their ice-polishing and striæ, while invariably blocks in the true boulder clay drift are beautifully polished and scratched. In his fourth comparison he appears to believe that the drift left by local glaciers, or *Moraine drift*, can contain very little mud, while in one, at least, Irish locality, as will hereafter be mentioned, there seems to be a true Boulder clay drift that apparently owes its origin to a local glacier. The fifth comparison does not seem capable of being applied to any of the Boulder drifts in Ireland, as the author has not met with a record of any fossils found therein.\*

If Principal Dawson's comparisons are correct, the *Boulder clay drift*, in general, ought to be partly of marine origin, while the *Moraine drift*, which sometimes overlies it, and also the *Rocky Moraine drift*, found in mountainous districts, would be formed by glaciers. The last named drift should not be confounded with the *Rocky drift*, found on parts of the central plain of Ireland, for this latter is always, more or less, allied to the *Esker drift*, as demonstrated in the author's former paper,† being the residue of the partly washed away *Boulder clay drift*, while the *Rocky Moraine drift* is seemingly an unaltered drift, the residue and *debris* left on the rounded, polished, and scratched rock surfaces, when the glaciers on the hills finally disappeared. Against the *Boulder clay drift* being partly of marine origin, it may be urged that the "Esker-like mounds" of that kind of drift, called by the Rev. Mr. Close, in his paper on "The Glaciation of Ireland," "Drumlins,"‡ which are so common in some localities, prove that this drift could not have been at the first deposited in anything like "a more or less uniform sheet." Secondly, the drift in

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\* Fossil localities in older and newer drifts will be found at the end of "Notes on some of the Drift in Ireland," already referred to.

† "Notes on Some of the Drift in Ireland."

‡ "Journal of the Royal Geological Society of Ireland," vol. i., p. 207.

such a locality as the south of Co. Mayo, north and north-east of Lough Mask, although apparently true *Boulder clay drift*, seems to be glacier-formed, having been brought to its present site by a glacier that flowed northward, its source being in the mountains west and south-west of Lough Mask. That these suppositions about the South Mayo drift are not improbable, would appear from the rock *debris* in it; as the latter, nearly altogether, are pieces of the rocks from the county about Lough Mask. Moreover, that this drift was formed by a glacier, and not by ice carried in a marine current, would appear to be proved, as the carrying agent, after it came down from the hills, seems to have brought its load partly northward, to form the drumlins on the north and north-east of Lough Mask, and partly southward, to form irregular drift hills on the east of Lough Corrib.

In answer to the first of these objections, it may be suggested that these "Drumlins" were formed subsequent to the first deposition of the drift, being the remains of the sheet of Boulder clay drift, they having been partly formed by local glaciers, and partly by marine currents. That they are partly of glacial formation, would seem proved by their longest axis always agreeing with the direction of certain glacial striæ, and that they are partly of marine origin, or, at least, that they have been subjected to the action of the sea, would seem to be suggested by the *Esker drift*, or *Post drift gravels*, in so many localities being found banked against them, or occurring in the hollows between them. Mr. Close, in the paper just now referred to, seems to be of the opinion that the drumlins were formed during the general glaciation of Ireland by land ice. He also appears to ignore all previous glaciation by icebergs, while the author, in his former paper, mentioned the suggestions, that the country was first traversed either by a gigantic ice stream that flowed from the N.E., or by icebergs carried in a similar direction, in a marine current, and that, subsequently, glacial systems, somewhat similar to those suggested by Mr. Close, existed, which carved out the drift. In favour of the last-mentioned ideas, it may be observed that the general bearing of the drumlins north and north-east of Lough Mask, coincide with the direction of the more recent of two systems of striæ found in that neighbourhood, as will be apparent from the following table\* :—

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\* In the writer's former paper, the striæ supposed to have been cut by *the ice carried in a marine current*, are called "Primary," as they are always the oldest, while those supposed to have been formed by *local glaciers* are called "Secondary"—According to this nomenclature the striæ in the first column of the accompanying table are the *Primary*, while those in the second are the *Secondary* of the Lough Mask Glacier.

Locality.	Older Striæ.	Newer Striæ.	Bearing of Drumlins.
Islands in, and mainland at the } N.E. of Lough Mask, }	—	{ N. & S. to N. 10. E.	{ N. 5. E. to N. 10. E.
West shore of Lough Carra, }	N. 25. E.	N. 10. E.	N. 5. E.
Aughinish between the S. end of } Lough Carra and Lough Mask, }	N. 28. E.	N. 15. E.	N. 15. E.
East of Lough Carra, }	—	{ N. 5. E. to N. 10. E.	{ N. 10. E.
Inish Maine (Lough Mask)	N. 55. E.	N. 15. E.	N. 15. E.
Two miles east of Ballinrobe,	N. 30. E.	—	N. 10. E.

The second objection would seem to have greater weight, as undoubtedly there are instances in which *Boulder clay drift* seems to be the residue left by local glaciers. However, in such cases, might not the glaciers possibly have flowed into a shallow sea, by which means the residue left should have a somewhat similar aspect to the drift said by Dr. Dawson to be deposited from icebergs, as the glaciers would flow along the sea bottom until the water became deep and strong enough to raise, break and float them away in icebergs? Moreover, this latter suggestion does not seem to clash with any of those put forward in the author's former paper.

If the sheet of *Boulder clay drift*, as suggested in the former notes, once extended up the sides of the hills, part of it would, during the subsequent glacial period, be carried down to the plains, and thereby account for the newer systems of striæ that occur associated with the drumlins. It ought to be mentioned, that many of the drumlins are known to have a nucleus of rock which may suggest their origin, as a mass of drift that lay against a rock would have a greater resistance and be more lasting than the drift in its neighbourhood, that had no auxiliary help to keep it in its normal position. It should also be observed, as perhaps it is in favour of the theory of *drumlins having been formed by land ice and not by icebergs*, that drumlins of undoubted *Moraine drift*, also of *Rocky Moraine drift*, occur frequently in mountain valleys, and on the slopes of hills.

As mentioned in the previous notes, Mr. Campbell, the author of "Frost and Fire," is of opinions somewhat similar to those of Dr. Dawson, but both these authors' suggestions are controverted in a subsequent publication by my colleague, Mr. Croll, who scouts the idea of icebergs being competent to grind or score the sea bottom, and even appears to believe they are incapable of adding much to the drift deposited in the sea.\*

This author brings forward telling quotations from Mr. Campbell's,

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\* "On Geological Time and the probable Date of the Glacial and upper Miocene Periods," by James Croll, of the Geological Survey of Scotland. *Philosophical Magazine*, November, 1868.

Dr. Sutherland's, and Sir Charles Lyell's publications, to prove that river ice and the ice observed in the straits of Belleisle, and off the coast of Labrador, polished, but did not striate the rocks. He also draws particular attention to the fact of stones, rocks, &c., occurring on icebergs, being remarked by so few voyagers; from which he seems to infer that if the icebergs are without graving tools, they are incapable of cutting, grooving, or éthing hard substances. He also suggests that Arctic icebergs have few places from which to receive blocks, as "Icebergs are chiefly derived from continual ice, such as that of Greenland, where the whole country is buried under one continuous mass, with only a lofty mountain peak here and there rising above the surface." However, Dr. I. I. Hayes in "The Open Polar Sea," while describing the breaking up of the ice during the Arctic summer, mentions the quantity of rock debris yearly carried to sea on the "Icefoot" and writes—"the amount of rock debris thus transported to the ocean is immense, and yet it falls far short of that which is carried by the icebergs; the rock and sand imbedded in which, as they lay in the parent glacier, being sometimes sufficient to bear them down under the weight, until but the merest fragment rises above the surface. As the berg melts the rocks and sand fall to the bottom of the ocean, &c."\* Also the late Dr. Kane, who, I believe, must be allowed to be no mean observer, says, when writing of the Eisfod or Ice belt, "as I looked over this ice belt losing itself in the far distance, and covered with its millions of tons of rubbish \* \* \* massive and ground to powder, its importance as a geological agent in the transportation of drift, struck me with great force. Its whole substance was studded with these varied contributions from the shore, and farther to the south, upon the now frozen waters of Marshall Bay, I could recognise raft after raft from the last year's ice belt, which had been caught by the winter, each one laden with its heavy freight of foreign materials." Subsequently, he writes, "I have found masses that had been detached in this way, floating many miles out to sea—long symmetrical tables, two hundred feet long by eighty broad, covered with large angular rocks and boulders and seemingly impregnated throughout with detrited matter." To those descriptions, he adds sketches of the ice rafts with their loads of blocks.†

From these quotations, Mr. Croll's suggestions as to the carrying powers of ice seem "not proven;" yet, it must be observed that no facts can be brought forward to gainsay his opinion, "that icebergs cannot striate the floor of the sea."

Before leaving this subject, it may be suggested that the icebergs met by ordinary navigators, do not appear in general to be those floated off from the Arctic glaciers, but seem, for the most part, to be formed from the breaking up of ice-fields, such as that which, during the winter, blocks up Smith's Sound. Such icebergs could only contain

\* "The Open Polar Sea," by Dr. I. I. Hayes, page 303.

† Arctic explorations, Vol. II. p. 155, *et seq.*; and for Sketches, pp. 138, 156, and 157.

blocks, when a *glacier-berg* had been caught in and incorporated with the field, and such a berg when met would not be in its normal condition, as on it, burying all the erratic block and *debris*, new ice ought to be formed during its winter stay in the field, under which circumstances all these foreign substances ought to be deep-seated, and only the non-block carrying portion should appear above the water. Moreover, until this ballast was melted off, and deposited on the floor of the ocean, the normal position of the berg should be stable, thereby preventing the blocks being seen by any passing observer, except in very rare instances.

*Moraine drift.* Among the hills of Yar, or West Connaught, and also on the slopes of many of them, especially the long, undulating slopes of ground bordering Galway Bay on the north, are large accumulations of the *Rocky Moraine drift*, containing local blocks and fragments, usually angular or semi-angular, some of enormous size, mixed with very sandy clay, or perhaps, more properly speaking, clayey gravel. Associated with it, is a drift in which most of the blocks are more or less rounded, sharply angular rocks being rare; and it is not uncommon for the latter, in places, to merge into a drift, composed of clayey gravels and sand. The Rocky Moraine drift occurs in most irregular-shaped small hillocks, scattered about, generally thickly together, but sometimes otherwise, and in them, on them, and between them, are innumerable blocks of all shapes and sizes, up to tons in weight. This drift more usually is found on the slope of a hill, or in a sloping valley below a *maum*, or "connecting mountain-gap," that always lead from an area of high land on which, it may be conjectured, in former ages, a sheet of perennial snow on a *mere-de-glace* existed, while its associate, in which the boulders are rounded, occurs in the low-seated valleys, such as that which leads from Oughterard to Clifden, where it may be supposed it came under the influence of water, the clayey matter thereby being lixiviated, and the blocks and fragments of rock rounded by the action of the waves, combined with the abrading action of the sand drifted by the currents. The blocks in the Moraine drift, although rounded and often scratched, are rarely finely polished. This may be caused by their matrix being a sandy clay, and in a true Boulder clay drift the fine polish on the blocks may have been caused by the unctuous clay acting as a polishing putty.

It should be mentioned that the gravel and sands which form part of these valley drifts, are not of the sharp clean nature of those that generally compose the *Esker drift*, but are more similar to the sand and gravel deposited in alluvial flats by rivers. Some eminent geologists have put forward the statement that glaciers can do very little work in deepening these valleys, compared with the work done by the meteoric agents, seemingly quite forgetting that *at all times* the river from a glacier is employed carrying away the waste, while the waste from meteoric abrasion can only be removed during floods. They may say that one flood would remove more waste than a glacial river in a month;

however, this does not seem to be proved, for no muddy river during a flood has more matter in suspension than an ordinary glacial river.

It seems to have been overlooked that many valleys are cut transversely across hard and soft strata, paying very little regard to the nature or structure of the rocks that have been cut away. Forces like ordinary meteoric abrasion or marine denudation work along soft portions, joints, fissures, or other weakened structures of rock masses, while a planing force like ice would cut across everything, sinking deeper where the strata were soft, and thereby leaving ridges across, of the harder materials. Moreover, if afterwards marine or meteoric abrasion modified the form of such a valley; either of these forces would be inclined to widen the valley in the places where the rocks are soft, also along joints, fissures, and such weak portions; and these places, which were nearly or totally disregarded during the original formation of the valley by ice action, would be excavated out to form narrow deep transverse ravines and glens, while the harder rocks would be left as spurs or crags standing out from the side, and the waste of the softer rocks would be deposited, filling up the hollows behind the first formed cross ridges. Are not such conditions found in nearly every valley? On the north shore of Camus Bay, which is part of the waters in the archipelago, north of the mouth of the Galway Bay, it is strikingly apparent that the small bays and *cooses* run with the bearing of the ice striæ (about N. 10 E.), while the joints in the porphyritic granite (the rock of the country) are all transverse to these bays, thereby showing that their formation had nothing to do with the rock structure.

Notwithstanding that it does not strictly belong to this paper, it may be mentioned that although long ago attention was drawn to the phenomena of valleys rarely running along the axis of a synclinal curve, but very often along that of an anticlinal, yet apparently when the formation of valleys is being inquired into, these facts have been quite lost sight of. If the movements in the earth's crust, as some geologists would wish us to believe, had little or nothing to do with the formation of the valleys; the present valleys ought to be more often in the troughs of synclinal curves than elsewhere. But does it not seem apparent, that the present courses of most of the main valleys originally more or less owe their origin to these movements? For the disturbing forces would rupture and break the rocks on the anticlinal curves, and also in most instances open fissures along the axis, thereby leaving lines of country broken, and therefore an easy prey to be carried away by any denuding force; be it marine, meteoric, or glacial.

Since the above was written Mr. Clarence King has published an account of the "Glaciers on the Mountains of the Pacific Slope," from which the formation of the "Rocky Moraine Drift" may be fully accounted for. ("The American Journal of Science and Art," 3rd Ser., vol. i., No. 3, p. 157.)

V.—ON THE “GEOLOGY AND EXTINCT VOLCANOES OF CLERMONT, AUVERGNE.” By RICHARD G. SYMES, F.G.S. (Map and Plates II. III.)

[Read April 12, 1871.]

It was my good fortune last summer to visit this most interesting locality in company with my colleague, Mr. Leonard. The district has already been visited and described by such eminent geologists, as Sir Charles Lyell, Sir Roderick Murchison, Prevost, Bertrand de Doue, Le Coq, Bouillet, Rozet, Pissis, Ruelle, and last, but not least, that well-known authority, Poulett Scrope, whose popular works “on the Volcanoes of Central France,” as well as that “on Volcanoes,” proved a ready source of information, as well as guided us in our pursuits after a thorough knowledge of those rocks, which may be considered as identical with those of our own island.

We took up our quarters at Clermont Ferrand, the capital town of the department of the Puy-de-Dome, in the province of Auvergne.

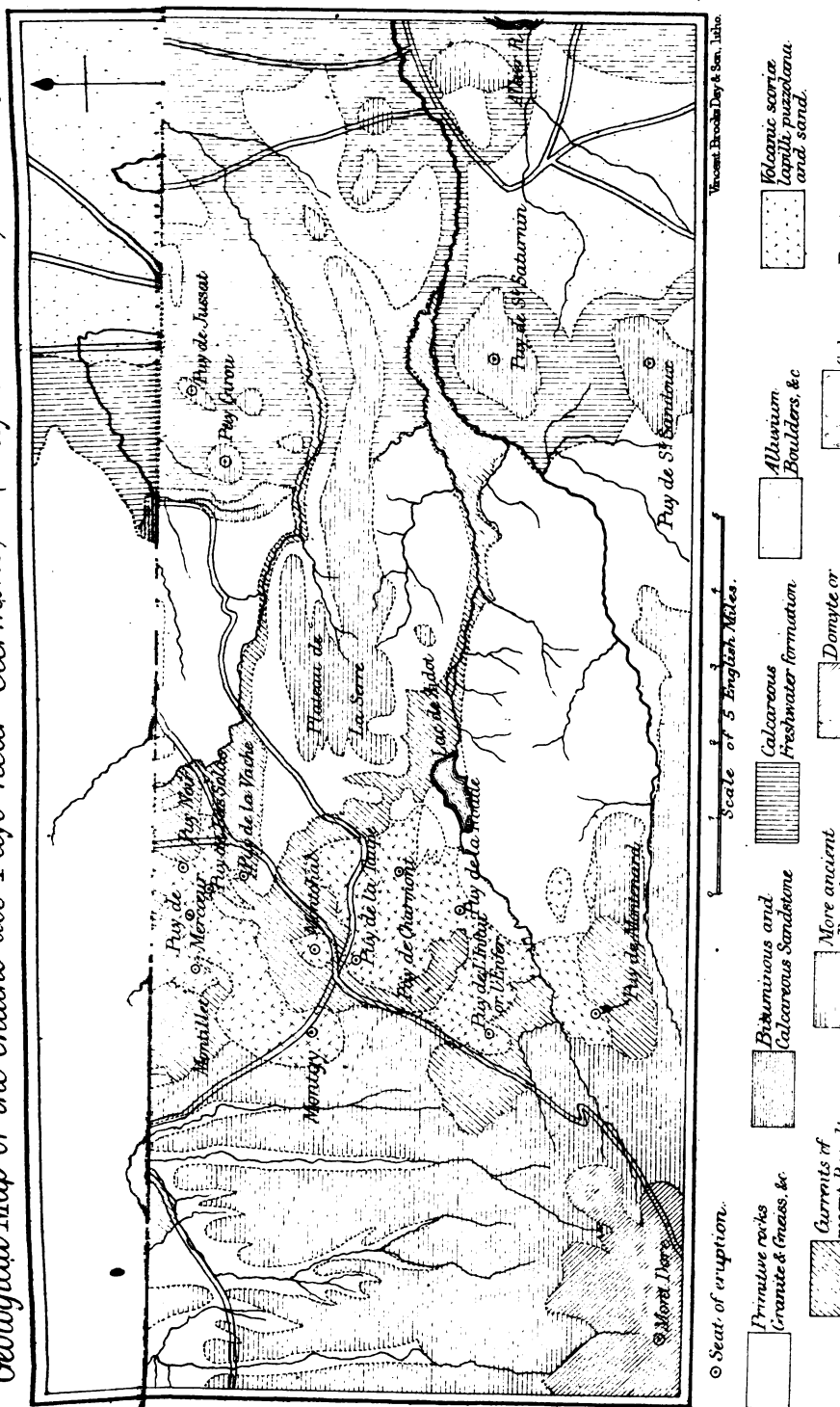
Clermont lies about 300 miles S. S. E. of Paris, about 1200 feet above the level of the sea. It is situated on a conical eminence in the valley of the Allier; which river runs northwards and joins the Loire at Nevers. The country we chiefly examined lay between 4 and 5 miles West of Clermont on comparatively high ground, as before you ascend to the region where this vast collection of extinct volcanoes exist, you must pass across the granitic plateau on which these monuments are supposed to rest, and which is about 1500 feet above the town of Clermont (see Map). The rocks of the district under our notice were *Plutonic rocks*, *Aqueous rocks*, and *Volcanic rocks*.

*Plutonic Rocks.* The granitic plateau extends for a considerable area in a N. and S. direction, retaining for the most part a uniform height above the plain. It is plainly discernible from a distance that its composition is granite, as its surfaces are weathered out in rounded tumuli, presenting a soft and pleasing outline more or less devoid of vegetation, and traversed by innumerable small valleys and deep ravines, which convey the drainage from the high ground to the river Allier, on the E. and to the River Sioule on the W.

The granite which is found along this plateau varies very much in composition and texture. It generally has two micas (margarodite and lepidomelane; the latter predominating in nearly every case over the other), one felspar, oligoclase; and glassy quartz.

In proportion as the granite is close to the rocks of volcanic eruption, so is its decomposition more readily affected, and wherever a contact was observed of the basalt on the granite, the latter was always changed to a red brick colour, and could be reduced to powder by the mere pressure of the fingers on it.

*Aqueous Rocks.* The town of Clermont rests on what is termed the lacustrine strata, which is supposed to be due to fresh water for-





mation, and to be of the age of the Upper Eocene, or Lower Miocene period. These lacustrine strata in this neighbourhood are for the most part of—1, grits (conglomerate, sandstone, coarse and fine); 2, marls of various colours; 3, indusial limestone or travertine.

1. The grits composing the lower part of the series were found in juxtaposition to the granite, and at first were mistaken for granite; however, we were soon undeceived on that point, as lower down in the series the grains become larger, and to the naked eye were observed to be round. They are for the most part composed of the debris of the granite and basalt, bound together by a siliceous cement. I have in my possession a specimen containing a fine well rounded pebble of basalt. The presence of the basalt pebbles, in these grits and conglomerates is totally at variance with the opinions of such eminent men as Sir Charles Lyell and Mr. Scrope, well-known authorities on volcanic rocks.

Sir Charles Lyell, who, in company with Sir Roderick Murchison, visited Auvergne subsequent to Mr. Scrope, writes,\* “Strata of sand and gravel, sometimes bound together into a solid rock, are found in great abundance around the confines of the lacustrine basin, containing in different places pebbles of all the ancient rocks of the adjoining elevated country; namely, granite, gneiss, mica schist, clay slate, porphyry and others, but without any intermixture of basaltic or other tertiary volcanic rocks.” Mr. Scrope describes these grits, “as some beds consist of a conglomerate of worn pebbles, and fragments of granite, gneiss, mica schist, porphyry, the rocks of the adjoining elevated district, but without the admixture of basaltic or any other volcanic rocks,” also in another portion of his work, he says, “no traces of a volcanic character occur in the conglomerates or sandstones which constitute the lower terms of this fresh water formation.”

The finding of these specimens containing these rounded pebbles of basalt, must therefore give the time at which volcanic eruptions first took place in this district to be of a much earlier date than that to which the two authorities I have just quoted, have given.

2. *Variiegated Marls*.—These for the most part are generally green or white, but vary very much in colour in a short space; they are highly calcareous and are extremely thinly foliated, in some cases having calcareous peperino interstratified with them. The thin foliation of these marls is supposed to be due to the innumerable thin shells or carapace valves of that minute animal called *cyprie*, which is known to moult its integuments periodically, which the conchiferous mollusks do not. This foliation is often carried to such a degree, that as many as twenty or thirty laminæ may be counted in the thickness of an inch.

3. *Indusial Limestone, travertine, oolite*.—These are only seen where there is a considerable thickness of the sedimentary rocks, and as far as I could judge, always had a protective capping of basalt. They gene-

\* See Lyell's Manual of Elementary Geology, pp. 198 and 203.

† See Scrope's Volcanoes of Central France, pp. 8 and 14.

rally occur in beds about eight or ten feet in thickness, separated from one another by bands of marl or beds of oolite. When their upper surface is unweathered or broken, these beds present a very curious appearance; inasmuch as, what is at first seen is a mammillated or botryoidal mass, which in an intensely hard casing composed of concentric layers of a whitish or yellow ribboned carbonate of lime encircling the interstratified mass of soft travertine composed almost entirely of "indusiæ" or "cases," from which these beds are so called.

These cases or indusiæ correspond to what we can observe in our own ponds and lakes of the Phryganea (or Caddis fly); which has in its caterpillar state the power of affixing to its circular tube or case, numerous small fresh water shells, which cases they quit when their change from the caterpillar to the fly is complete. If, then, we suppose myriads of these cases encrusted with a stalagmitic matter, we find such a rock as that known as indusial limestone in Auvergne.

The shell with which these cases are encrusted is known as *Bulimus atomus*, and as many as a hundred are to be found encrusting a single case. The total probable thickness of fresh water formation that could be counted in this district is about 1000 feet.

Having thus disposed of the plutonic and sedimentary rocks, I now pass on to the rocks due to volcanic action, viz.: basalt, and trachyte.

*Volcanic rocks.*—The chain of craters and hills of volcanic eruption, rests on the granite plateau and extends in a N. and S. direction for about 20 miles, while the greatest breadth does not exceed 2 miles.

Their number is probably about 65, of which 60 are composed of lapilli, puzzolana, scorïæ, and basalt, while the remaining five are composed of pumice and trachyte.

*Trachytic or Domitic hills.*—The largest of the hills in this chain is the Puy-de-dome, which is about 4800 feet above the sea and about 2000 feet above the granitic plateau. It is composed of trachyte, which contains felspar, white mica, and an occasional crystal of tourmaline (?) or hornblende (?). One of the best exposures occurs on the N. E. slope, of yellow, white and red trachytic porphyry, which decomposes rapidly.

Next in height of the trachytic hills are Puy-de-Clersou (3992); Puy-de-Chopine (3910); and Le Grand Sarcouii (3799).

Of these the most remarkable is the Puy-de-Chopine, which consists of beds of granite and syenite between basalt and masses of trachyte; but the hill from which most is learned is Le Grand Sarcouii (see Plate II.).

This hill is about two miles to the N. N. E. of the great Puy-de-Dome, and is encircled by scorïaceous hills of Le Puy des Goules, and Le Petit Sarcouii. Very little evidence of its composition is to be seen on its W. N. or E. sides, which are clothed with stunted brushwood and heather, but on the S. and S. E. sides ample evidence is obtained of its domitic composition. This rock, when first observed, presents a dusty-grey appearance, and is reducible to a white powder by a common penknife. On the S. E. sides good exposures were observed, the rock appearing as it were stratified, each layer varying in thickness, and forming concentric folds, being parallel to the shape of the hill. A good section is

seen in the caves, which are in the S. of the hill and near its summit, and which have been worked for sarcophagi. Here the concentric layers are well seen, and are composed of trachyte devoid of crystallization, and tinted of various hues, supposed to be from the fumes of muriatic acid. The shape of this hill is somewhat like an opened umbrella, or of the ordinary felt hat without a brim: its sides are very steep, the top joining in with the sides by a very sharp curve; its uniform appearance throughout makes it different in aspect from the other domitic hills, on each of which there seems to have been an outburst of trachyte on some point forming a rude escarpment and of irregular outline.

*Theory of their formation.*—Of the domites or trachytes, there is no evidence in the low country, no plateau is capped with this remarkable rock, no current to be met with; neither could I obtain any evidence in the drift (which is to be seen in the low ground composed of basalt and granite, and limestone) of any blocks or pebbles of trachyte or pumice.

The reason then adduced for there being no evidence of this acidic rock, far from the seat of its ejection, is, that it was ejected in an imperfect state of fluidity; and being of low specific gravity, could not flow.

Various theories have been stated with regard to the formation of these bell-shaped hills; Von Buch's being, that these masses are hollow, and were blown up like a bladder. Dolomieu, Mossier, and Montlosier, were also of the same opinion. Desmarest considered them as a granite calcined *in situ* by some great volcanic conflagration encircling it. Ramond considered that they were detached portions from the Mont Doré trachytes. Scrope considers that as these trachytes possess the lowest specific gravity, on account of their being composed almost wholly of felspar, the tendency of the ejected mass would be to accumulate around the orifice, one layer of the congealed and inert substance spreading over that which preceded it. My own theory with regard to these hills is, that their section exactly coincides with that of the adjoining cinder cones: that pumice was ejected, which accumulated around the orifice in the form of a cone and crater, and that when the crisis had arrived or the trachytic lavas commence to swell forth, instead of bursting through the sides of the crater, which is generally the way with a basaltic lava, it rose to the top of the crater and flowed gently over, thereby forming those concentric folds so apparent in Le Grand Sarcouii.

*Scoriaceous or basaltic hills.*—These splendid examples, built on the site of where once violent eruption took place, are very little affected by atmospheric action either externally or internally, and stand out on the vast plateau more or less disconnected with one another, either as true cones with their apex cut off, or in the form of breached cones.

As good examples of true cones, there is the Puy des Goules and Puy des Pariou, and for breached cones, Puy Noir and La Vache.

*True cones.*—The true cones have invariably the adjunct of what is termed the crater, or depression in its centre—the centre of which

crater marks the spot from whence the mass was ejected, and the whole presents very much the appearance of an inverted cone within a cone. The crater of the Petit Puy de Dome, which immediately adjoins its colossal neighbour Le Grand Puy de Dome on its N. side, shows very well the manner of construction of these cones; as on its S. side a section was observed of stratified puzzolana and lapilli dipping inwards and outwards at an angle corresponding to both, viz.  $35^{\circ}$ . This crater is about 120 feet deep measured from its lowest side, and the bottom is 45 feet in diameter. Its sides are clothed with a short herbage consisting of grass and heather. These sides are too steep for cattle to graze on, either ascending or descending, accordingly they graze in contour paths around the crater, each path being somewhat better than a foot above the lower one. This, as we first viewed it of a July evening from the top of Le Grand Puy de Dome, which is more than 600 feet above that of Le Petit Puy de Dome, presented to the eye a vast amphitheatre in which a very large herd of cattle were grazing. Tier above tier took the circuit of the entire crater, picking up what scanty food they could find, and then passed out and down the cone to the lower ground, to seek shelter for the night in the stunted woods which grow at its base\* (see Plate II.).

The cone of the Puy de Pariou is extremely perfect, and has in conjunction on its western side portions of a breached cone, the summit of which is about half the height of the perfect cone measured from its base. This shows how that originally there was a perfect cone here which was breached by a large emission of lava, and that when the lava had ceased to flow the centre of eruption was changed and a new pile formed unbreached, as we now find it.

It has a very perfect crater, the sides being stepped, and about the same angle as that of the Petit Puy de Dome; it is somewhat larger and slightly different in shape, inasmuch as this one is somewhat elliptical, the longer axis running N. and S. showing the vent to coincide with the general bearing of the chain.

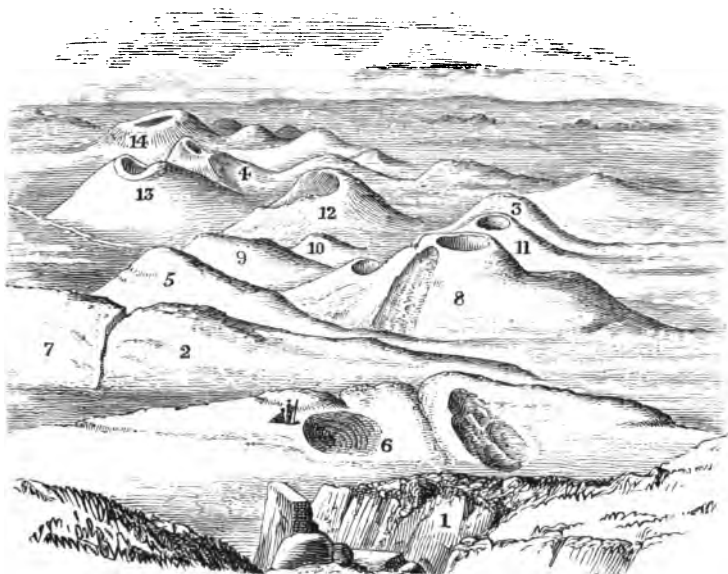
*Breached cones.* So called from the breach or gap in some side, through which the lava forced its way subsequent to the filling up of the cone.

*Basalt or dolerite.* From the most of these several cones proceeded lava, the usual accompaniment of volcanic eruptions, which lava, owing to its high specific gravity and perfect fluidity, flowed steadily onwards (in this district generally E. and W.), seeking as it were by valleys and ravines the low ground, and there swelling forth until stopped by its imperfect fluidity.

Of some of these basaltic lavas I will give a brief description. They are arranged into two divisions, viz., present or recent, and past or ancient.

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\* The cattle that feed on these cinder hills are all shod on the outer hoof with a flat plate, which must either be for the purpose of protecting the hoof from wearing, or to give the animal a certain grip on the steep slopes, as the five nails with which the plate is fastened have similar heads to the ordinary horse shoe nail of this country.



PANORAMIC VIEW TAKEN FROM THE TOP OF LE GRAND PUY DE DOME,  
LOOKING NORTH.

DOMITIC PUYs.

1. LE GRAND PUY DE DOME.
2. LE PETIT SUCHET.
3. LE GRAND SARCOU.
4. PUY CHOPINE.
5. CLIERSON.

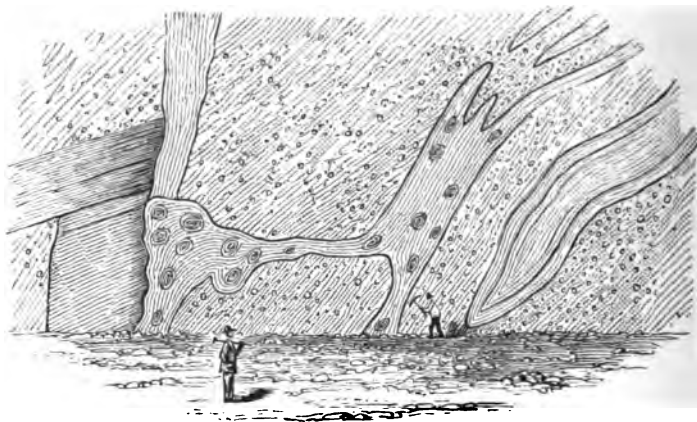
VOLCANIC PUYs.

6. LE PETIT PUY DE DOME.

7. LE GRAND SUCHET.
8. PUY DE PARION.
9. PUY DE LA FRAISSE.
10. LE CREUX MOREL.
11. PUY DE GOULES.
12. PUY DE CHAUMONT.
13. PUY DE LA GOUTTE.
14. PUY DE LOUCHADIÈRE.







SECTION AT ROYAT.—BASALT AND SCORIA.

*Recent lavas.* They are all of the same age as the cones, and are to be found at the base of some of the cones, on the granitic plateau as well as in its ravines, and in the low ground adjoining the town of Clermont, as well as in the low ground westwards in the valley of the Sioule.

Their composition apparently does not vary very much. They change from the very compact to vesicular and highly vesicular in a very short space, the centre of a flow being generally compact while the upper and lower portions of the flow are vesicular, elliptical in section, with the longer axis parallel to the direction of the flow.

No lava was observed to be crystalline, but in the vesicles and geodes crystals of olivine, augite, and obsidian, were observed. The form these lavas assume after cooling also varies very much in a short space. In one quarry N. of the Plateau of Prudelle we found spheroidal, tabular, and rudely prismatic, all of which were exfoliating.

Of the thickness of these recent lavas I saw none to exceed 50 feet, that is measured at right angles to the flow. Mr. Scrope mentions that at Royat, which lies about three miles W. of Clermont, he saw basalt 60 feet thick. There large excavations have been made recently for building stones, as well as scoræ for road metalling, and some splendid sections occur of the basalt lying at high and low angles on scoræ and lapilli. I suspect then that the thickness measured was vertical thickness, which is about 60 feet, and which probably at the time Mr. Scrope examined the place was not so well exposed as it is now (see Plate III.).

At Beaumont, which lies to the S. of Clermont, the flow supposed to be the same as that at Royat, and to be from the neighbouring Gravenere, is very well seen both on its N. and S. sides. Great huge cresting waves of basalt, forming as it were concentric folds on the mass, which appears as a great wall running out into the low country.

In an extensively worked quarry to the N. E. of Beaumont a magnificent section of the basalt was observed. At first sight it looked like the dark blue conchoidal limestone so often seen in Ireland, and appeared to have a horizontal structure; however, on nearer approach the columnar structure is plainly discernible, and no sign whatever of horizontal structure, but the colour changes from black in top and bottom to a good blue in centre, also the vesicles, which were apparent and very abundant in top and bottom, die out altogether in the centre where it is a highly compact mass.

The thickness of this mass is just 50 feet, and has a capping of scoræ as well as lapilli. On the western side of the quarry the mass rests on scoræ and rounded granite blocks, which occur in a hollow. The granite blocks are of a bright red colour and decompose very rapidly. At the eastern side the mass rests on the stratified and very thinly laminated variegated marls, which for a thickness of exactly two inches are highly indurated, showing how little was effected in a metamorphic way by this great molten mass.

*Ancient lavas.*—These are for the most part to be found on the fresh-water formations E. of the great central axis, and on the granites W. of it. They occur in the form of plateaus or nearly horizontal sheets

capping the fresh-water formations and standing out as relics untouched by the denuding agencies which have carved the outlines as we now find them.

They appear to be capable of sub-division into No. 1, or older, and No. 2, or newer.

No. 1, is the most ancient lava of the whole district, which was emitted when probably the waters of the fresh-water lagoon were higher than the present elevation of the granite plateau, and over which was subsequently deposited about from 30 to 60 feet of marls, which in its turn was capped by No. 2 or the newer basalt. The thickness of the most ancient sheet probably does not exceed 40 feet, and is for the most part tabular, lying horizontal or at a low angle away from the central axis. It invariably has its pockets or vesicles filled with carbonate of lime.

I presume then to say, that this No. 1 basalt was emitted from some great vent occurring along the great central axis where now exist the monuments of recent eruption, and that the tract, commencing at the plateau of Chateaugay on the N. and ending with that of La Serre on the S., was at one time covered with this nearly horizontal sheet, and which probably extended eastwards much farther than we have any remnants at present. Of No. 2 basalt, all that can be said of it is, that it bears a very striking resemblance to No. 1, save, that it is devoid entirely of the carbonate of lime in its vesicles, and nowhere did I find it covered by the fresh-water marls. No. 2 caps the entire plateau of Gergovia, and being tabular, proved a ready source for materials when it was occupied as a Roman encampment, a wall being built around the entire plateau of basalt slabs. On the S. E. side is a monument made of the basalt on which was the following inscription: "The 9th of July, 1862, at noon, His Majesty the Emperor Napoleon the III., after visiting the plateau of Gergovia, rested here."

No. 2 basalt on the Cotes des Clermont has not been remarked by Mr. Scrope. It occurs in three or four detached outcrops on the N. E. side of the hill, and is exactly similar to that on the plateau of Gergovia, save that it is at somewhat a higher angle.

On the Plateau of Prudelle, which lies to the W. of Clermont, the granite is capped with a sheet of basalt about 44 feet thick. On measuring the vertical section as exposed there, it was found as follows:

	feet.	inches.
On the granite, Bluish puzzolana cemented	4	0
Lapilli . . . . .	0	3
Scoriæ . . . . .	0	10
Tabular basalt . . . . .	32	0
Prismatical do. . . . .	12	0
	<hr/>	
	49	1

This basalt as a whole, might, I think, be composed of No. 1 and No. 2, as the top is so different in structure from the bottom; yet there appears to be no joint between the two.

The top consists of many-sided prismatical basalt, while at the bot-

tom there is no sign whatever of columnar form, but on the contrary is extremely tabular and flaggy. When examining the surface of this plateau for some striæ or traces of the denuding agent, which must have been at work close at hand, I detected hollows or as it were shallow basins evidently due to subsidence on the cooling of the lava and showing that this at least was free from the forces brought into play as carvers and exterminators.

*Waters.*—In the neighbourhood of Clermont, are two remarkable springs, one in the town, viz.: that of St. Alyre, which is highly charged with carbonate of lime, and which proves a source of considerable profit to those in proximity to it, as by changing the course of this stream into houses, which for the most part are filled with ladders on which are placed all sorts of things, such as fruit, eggs, artichokes, prawns, cameos, &c., and allowing the spring to pass over them, they in the space of about two months become coated to about  $\frac{1}{10}$  of an inch with carbonate of lime, and are readily sold at a small price. The other spring is in the village of Royat, about three English miles from Clermont and is thermal, being used by invalids for drinking purposes as well as for baths; it contains a fair proportion of sulphuretted hydrogen, and deposits a silicate of lime. Both of these springs although rising through the lacustrine strata have their origin in the granite.

The town of Clermont is supplied by water from a place in close proximity to the thermal spring at Royat, but from water which apparently only has percolated through the volcanic scorïæ, &c., of the high ground to the west.

*Conclusion.*—The inferences then that are drawn from this remarkable district are:—

1. That the condition to which these volcanoes are applicable to, is that of the phase of prolonged inertness, viz.: that in which eruptive paroxysms of intense energy alternate with lengthened periods of complete inertness.
2. That the cinder cones, domitic hills, and recent lavas are all due to one violent paroxysm spread over an area 20 miles long by 2 broad.
3. That the presence of two such different rocks as basalt and trachyte in such close juxtaposition, can only be accounted for on the supposition, that the rocks from which they are derived, viz.: hornblende rock and some highly felspathic rock such as granite, were in contact, prior to their being reduced to the forms we now find them in.
4. That the granite plateau was very much in the same condition prior to the deposition of the lacustrine strata, to that as now exists, that is to say, it was high ground.
5. That even prior to the deposition of the lacustrine strata, this was probably the seat of volcanic eruption.
6. That between the recent and ancient lava flows, there were vast denuding agencies at work in the shape of atmospheric action, as is seen by the configuration of the ground as now exists, and with that as supposed to exist prior to the ancient flows.
7. That the most ancient lava was deposited while the fresh water existed, and that the flow next in age was deposited immediately on the retreat of said water.

VI.—REMARKS ON THE GENUS *PLEURORHYNCHUS*, WITH A DESCRIPTION OF A NEW SPECIES. By WM. HELLIER BAILY, F. G. S., L. S.

[Read April 12, 1871.]

THE genus *Pleurorhynchus* of Phillips, *Conocardium* of Bronn, is generally believed to be allied to the *Cardiadæ*, although its true relations are somewhat obscure; the species then known were included with *Cardium* by Sowerby (*Min. Conch.*, 1823), being also placed in the same genus by Goldfuss.

This group of shells are equivalve, trigonal, and gibbous, the posterior (not the anterior end, as it has been usually considered), is truncated, and in most of the species furnished with a long, slender, siphonal tube. The exterior of the shell is ribbed or finely striated, and exhibits a prismatic-cellular structure; the hinge is furnished with anterior and posterior laminar teeth, the ligament being external.

The geological range of the genus is from the Caradoc strata of the Lower Silurian formation, to the Carboniferous Limestone. The species described from British strata are as follows:—

*Pleurorhynchus dipterus* (*Salter*), Caradoc, Ayrshire, and Chair of Kildare.

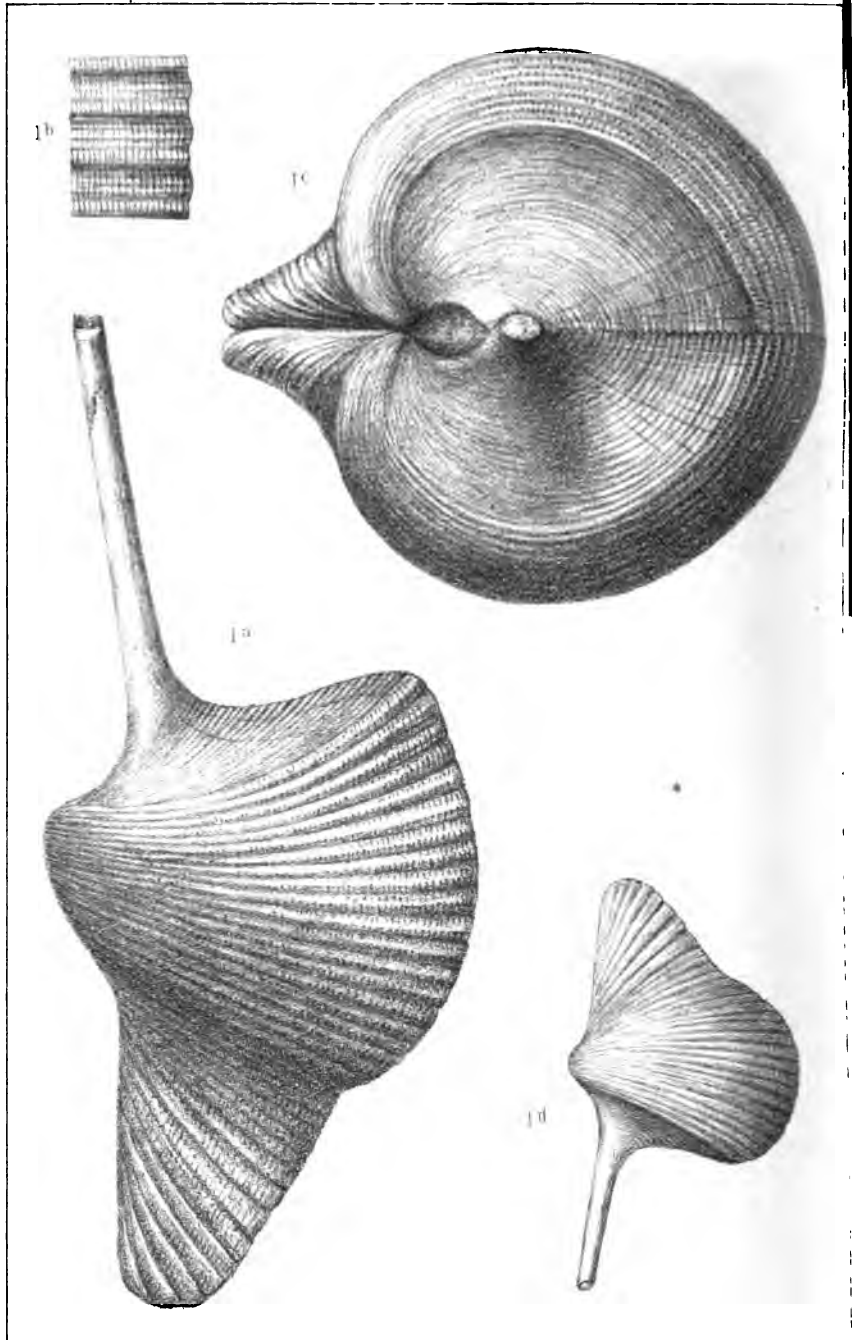
- „ *pristis* (*Salter*), Llandoverly rocks, Co. Galway.
- „ *æquicostatus* (*Phillips*), Wenlock rocks, Woolhope, and Dudley.
- „ *calcis* (*Baily*), Wenlock rocks, Co. Tipperary.
- „ *aliformis* (*Sowerby*, sp.), Devonian and Carboniferous Limestone.
- „ *minax* (*Phillips*), Devonian and Carboniferous Limestone.
- „ *armatus* (*Phillips*), Carboniferous Limestone.
- „ *elongatus* (*Sowerby*, sp.), ditto.
- „ *Hibernicus* (*Sowerby*, sp.), ditto.
- „ *fusiformis* (*M'Coy*), Carboniferous Limestone (lower Malahide, and Hook Head (W. H. B.).
- „ *nodulosum* (*M'Coy*), Carboniferous Limestone.
- „ *Koninckii* (*Baily*), ditto.

This list includes four species (all comparatively small shells) from Silurian rocks, and eight from the Carboniferous Limestone, two of the latter (*P. aliformis* and *P. minax*) commencing in Devonian strata. During the formation of the Carboniferous Limestone this genus, therefore, attained its maximum development.

*P. elongatum* (*Sowerby* sp.) is referred in Morris's Catalogue of British Fossils to *P. rostratum*. I think, however, the original name should be retained, as it is certainly not *P. rostratum* of De Koninck; *P. inflatus* (*M'Coy*) appears to me to be a synonym of this species.

*P. giganteus* (*M'Coy*), *Synopsis Carb. Foss. Pl. XL*, fig. 1, is I believe nothing more than *P. Hibernicus* showing its large expanded keel.





W.H. Bailey, del et lith.

Forster & Co. Dublin.

Fig. 1 a-d. *PLEURORHYNCHUS KONINCKII* (Bailey)

*P. trigonalis* (Phillips) is referred by Bonn to *P. aliformis* and *P. Hibernicus*.

*P. rostratus* (Martin), Morris's Catalogue of British Fossils, p. 9, 5, appears to me to belong to *Arca* or *Cucullæa*.

The following species, some of which are additional to those mentioned above, are included in Bronn's Index Palæontologicus as occurring in foreign Devonian, and Carboniferous Limestone strata:—

- P. (Conocardium) Bilsteinensis* (Roemer, sp.), Devonian.
- „ *armatus* (Sowerby, sp.), ditto.
- „ *Hibernicus* (Sowerby, sp.), ditto.
- „ *Uralicum* (Keyserling), Carb. Limestone.

*P. procumbens* (Sandberger) is referred to *Cardium Lyellii*. Sandberger in his Devonian fossils of Nassau also describes an additional species, *P. (Cardium) brevisulatus*, from Devonian strata; and De Koninck, in his Carboniferous Fossils of Belgium, that of *P. (Cardium) strangulatus* from Carboniferous Limestone.

The species I have now to describe was first noticed by me in connexion with other remarkable Carboniferous Limestone fossils from the county of Limerick, in the collection of the Geological Survey, and its name recorded at the meeting of the British Association in Dublin (1865) as *Conocardium Koninckii*. It was first pointed out to me as being a new species by my friend Professor De Koninck; I therefore named it after that palæontologist. Until this time no description has, however, been published of it. This species attains a large size, and is not uncommon in the Lower Limestone near Rathkeale, County of Limerick.

*Pleurorhynchus Koninckii* (Baily). Plate IV., fig. 1, *a*, *b*, *c*.

Description.—Shell trigonal, very gibbous, much elongated and contracted towards the anterior extremity, which is wing-shaped and gaping at the ends; posterior extremity truncated, heart-shaped, covered by fine concentric striations, and provided with a long siphonal tube; substance of the shell thick, with a prismatic-cellular structure; surface covered by slightly-raised radiating ribs, crenulated, and having intermediate striæ; ribs widely distant, about twenty in number, on the prominent portion of the shell, and twelve on the winged part.

Dimensions.—Length three inches, not including the siphonal tube, which is two or more inches long; height of largest specimen  $2\frac{1}{2}$  inches, thickness of ditto  $2\frac{1}{2}$  inches.

This fine shell approaches most nearly to *P. aliformis*; it differs, however, in being less elongated, and is more gibbous, the ribs not being so prominent; it also attains a much greater size.

The habits of these shells were probably similar to those of the elongated species of *Cardium*, which are found in the brackish waters, and burrowing in the sandy mud on the shores of the Aral and Caspian seas, being provided like them with elongated siphons, and having the shells gaping anteriorly for the passage of the foot.

VII.—ANALYSES OF SOME GRANITIC ROCKS FROM INDIA, AND OF THEIR CONSTITUENT MINERALS (1868). By MONTAGUE H. ORMSBY, Esq., of the Indian Geological Survey. [Communicated by the Rev. Dr. Haughton, from copies of Mr. Ormsby's Analyses made in 1868.]

[Read 10th May, 1871.]

No. 1. STRATIFIED gneiss, from Lower Bengal; composed of quartz, oligoclase, and margarodite; found in beds, from 1 to 3 feet in thickness, strike E. W., dip N. 70°; contains occasionally garnet, schorl, and epidote:—

*Stratified Gneiss.*

Silica, . . . . .	69.00
Alumina, . . . . .	18.76
Peroxide (iron), . . . . .	1.40
Lime, . . . . .	2.85
Soda, . . . . .	6.12
Potash, . . . . .	1.31
Water, . . . . .	1.20
	<hr/>
	100.14

The oligoclase and margarodite, of the preceding rock, had the following composition:—

*Oligoclase.*

Silica, . . . . .	64.20	
Alumina, . . . . .	22.84	
Lime, . . . . .	3.13	3.24
Soda, . . . . .	8.72	8.64
Potash, . . . . .	0.84	0.92
	<hr/>	<hr/>
	99.73	99.84

*Margarodite.*

Silica, . . . . .	45.60	
Alumina, . . . . .	31.24	
Iron peroxide, . . . . .	6.40	
Lime, . . . . .	0.24	} 1.07
Magnesia, . . . . .	0.84	
Soda, . . . . .	1.00	0.65
Potash, . . . . .	10.44	11.42
Water, . . . . .	3.60	
	<hr/>	<hr/>
	99.86	99.98

No. 2. Porphyritic gneiss, from Lower Bengal; consisting mainly of quartz and black mica, with orthoclase crystals imbedded in it, so as to produce an amygdaloidal porphyry:—

*Orthoclase.*

Silica, . . . . .	65.04
Alumina, . . . . .	19.60
Lime, . . . . .	0.89
Magnesia, . . . . .	trace.
Soda, . . . . .	2.48
Potash, . . . . .	12.60
	<hr/>
	100.61

No. 3. Stratified gneiss, from Galle Harbour, in Ceylon; strike E. W., in vertical beds. The orthoclase of this gneiss looks like adularia, and has the following composition:—

*Orthoclase.*

Silica, . . . . .	64.40
Alumina, . . . . .	19.60
Lime, . . . . .	0.96
Magnesia, . . . . .	trace.
Soda, . . . . .	3.04
Potash, . . . . .	11.60
	<hr/>
	99.60

VIII.—ON THE ANALYSIS OF TRACHYTE PORPHYRY, FROM TARDREE QUARRY, NEAR ANTRIM. By EDWARD T. HARDMAN, Associate Royal College of Science, Ireland, F. R. G. S. I., of the Geological Survey of Ireland.

[Read May 10, 1871.]

THE analysis which I shall lay before you this evening is that of a trachyte porphyry, obtained from Tardree Quarry, near Antrim; the specimen used in the investigation was given me by Professor Hull, Director of the Geological Survey of Ireland.

As the result differs in some respects from any published analysis of trachytic rocks that I have had an opportunity of making myself acquainted with, I have thought it might be considered of sufficient interest to be laid before the Society.

The portion obtained for analysis consisted of a light grey, hard, but brittle felspathic matrix, in which were set well-formed crystals of Sanadine felspar, about  $\frac{1}{8}$  inch in diameter,\* together with numerous small crystals of smoky quartz. A few very minute crystals of hornblende were also discovered on careful examination. No effervescence whatever took place when the rock was treated with either strong or dilute mineral acids. The specific gravity was 2.433.

A small quantity was crushed, and separate portions submitted to the action of concentrated hydric sulphate, potassic hydrate, and dilute hydric chloride, respectively, in the hope that either of these solvents might remove the paste, leaving the crystals for examination. But as this promised to be a very tedious undertaking, and I had not then leisure to make such a perfect investigation of the rock, I was obliged to content myself with a collective analysis. The solution with hydric sulphate contained  $\text{CaO}$ ,  $\text{Al}_2\text{O}_3$ , trace of  $\text{Fe}_2\text{O}_3$ ; that with potassic

---

\* These crystals when taken out carefully, left perfect moulds, or casts, in the matrix, showing that they were formed before the paste cooled. This agrees with Scrope's statement, that lavas are usually poured out in a semi-fluid state, small crystals being already formed.



In these calculations the following atomic weights were used:—

Al = 27.5	. . . . .	Si = 28
Fe = 56	. . . . .	K = 39.1
Ca = 40	. . . . .	Na = 23
Mg = 24	. . . . .	P = 31
		O = 16.

The following is the percentage composition:—

SiO <sub>2</sub> =	76.960
Al <sub>2</sub> O <sub>3</sub> =	5.101
Fe <sub>2</sub> O <sub>3</sub> =	2.344
CaO =	7.064
MgO =	0.295
K <sub>2</sub> O =	4.262
Na <sub>2</sub> O =	1.818
Loss by ignition =	2.102
H <sub>3</sub> PO <sub>4</sub> =	trace
	<hr/>
	99.943

$$\text{S. G.} = 2.433$$

Besides the high percentage of silica, the large amount of lime and the small amount of alumina, at once arrest the attention; for except in a decomposed trachyte the alumina usually ranges between 9 and 13 per cent. for a similar proportion of silica, while the lime seldom exceeds, and rarely reaches, 2 per cent. It was for some time puzzling to account for this divergence from the circumstances usually obtaining in such rocks. The lime might be accounted for on the supposition that the matrix contained some labradorite, an occurrence that is by no means rare, according to Von Cotta and Bischof, or that the felspar crystals were of a plagioclasic nature. However, judging from the difficulty of fusion with the blowpipe, and resistance to acids, the quantity—if there be any—of such felspars, must be exceedingly small. Some crystals crushed, and allowed to stand all night after being boiled in concentrated hydric chloride, had given up little more than traces of their constituents.

A qualitative examination being made of some of felspar crystals gave the following result:—

SiO<sub>2</sub>.  
 Al<sub>2</sub>O<sub>3</sub>.  
 Fe<sub>2</sub>O<sub>3</sub> a trace  
 CaO.  
 MgO.  
 Na<sub>2</sub>O.  
 K<sub>2</sub>O.

The lime was here also in unexpectedly large quantities. It has no doubt here, as well as in the matrix, replaced some of the alumina,

owing to double decomposition taking place between aluminic silicates and water containing calcic sulphate, a reaction which is quite possible.\*

The ferric oxide is disseminated throughout the rock in little cavities, and is, perhaps, due to the decomposition of hornblende, which, as already mentioned, occurs sparingly.

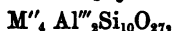
If we determine the atoms of silica and bases respectively, by dividing the percentage by the atomic weights, the following numbers are obtained :—

$$\begin{array}{rcl} \text{SiO}_2, & . & 1280 . . 1280 = 26 = \text{SiO}_2. \\ \text{Al}_2\text{O}_3, & . & 49 . . 49 = 1 = \text{Peroxide.}^\dagger \\ \text{CaO}, & . & 126 \\ \text{MgO}, & . & 7 \\ \text{K}_2\text{O}, & . & 45 \\ \text{Na}_2\text{O}, & . & 30 \end{array} \left. \vphantom{\begin{array}{l} \text{SiO}_2 \\ \text{Al}_2\text{O}_3 \\ \text{CaO} \\ \text{MgO} \\ \text{K}_2\text{O} \\ \text{Na}_2\text{O} \end{array}} \right\} . 208 = 4 = \text{Protoxides.}$$

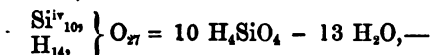
These numbers give the formula :—



or,



—which is that of a condensed poly-silicate formed on the type of 27 molecules of water, thus :—



leaving 16 atoms of  $\text{SiO}_2$  uncombined. These would represent the quartz, and its percentage would be 47.42.

If, however, for the sake of comparison, we stretch a point in the atomic calculations, we shall obtain this result :—

$$\begin{array}{rcl} \text{SiO}_2, & . & 1280 . . 26 . . . . 26. \\ \text{Al}_2\text{O}_3, & . & 49 . . 1 . . . . 1 \text{ peroxide.} \\ \text{CaO}, & . & 126 . . 3 \text{ (strictly 2.6)} \\ \text{MgO}, & . & 7 \\ \text{Na}_2\text{O}, & . & 30 \\ \text{K}_2\text{O}, & . & 45 . . 1 \end{array} \left. \vphantom{\begin{array}{l} \text{SiO}_2 \\ \text{Al}_2\text{O}_3 \\ \text{CaO} \\ \text{MgO} \\ \text{Na}_2\text{O} \\ \text{K}_2\text{O} \end{array}} \right\} 5 \text{ protoxides.}$$

which gives the formula :—



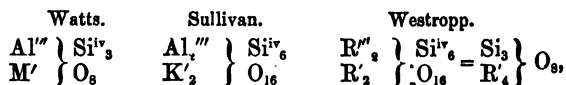
$$= \frac{\text{Al''}_2}{\text{M''}_5} \left\{ \left( \text{Si}^{\text{iv}}_6 \right)_{\text{O}_{16}} \right\}_2, \text{ or } \left. \begin{array}{l} \text{Al''}_3 \\ \text{Ca''}_3 \\ \text{K'}_2 \\ \text{Na'_2} \end{array} \right\} \left( \text{Si}^{\text{iv}}_6 \right)_{\text{O}_{16}} \right\}_2,$$

leaving 14 atoms of silica or quartz = 41.44 per cent.

\* Watts' Dict. of Chem., vol. ii., p. 835; Bischof's Elements of Chem. and Phy. Geo., vol. ii., pp. 68 and 105.

† The ferric oxide is not taken into account in these calculations, as I believe none of it is combined. Only traces were discovered on analysis of the felspar crystals, or of the paste when carefully selected, so as to be free from the yellow ochery particles.

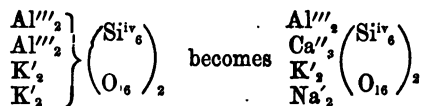
The most reliable formulæ for orthoclase felspar are those of Watts,\* Sullivan,† and Westropp.‡ These are:—



being to all intents and purposes exactly alike.

Now doubling the formula as given by Sullivan, and substituting for two of Al, and two of K, 3 atoms Ca, and two atoms of Na, we shall have a formula precisely similar to that one last given as calculated from the total analysis of the trachyte.

Thus:—



Considering the physical characters of the constituents of the rock already alluded to, I choose to take this as the theoretical composition of the mineral, of which, besides quartz, it is made up; and to call it orthoclase felspar,—much altered as to the relative quantities of the metals,—or bases; but normal in molecular arrangement. Believing, also, that the slight deficiency of Ca and Na is due to the well known fact that when alterations take place in minerals, the substances abstracted are not always entirely replaced by their substitutes.

The mineralogical composition of the trachyte is therefore:—

Quartz	41·440
Orthoclase	54·886
Fe <sub>2</sub> O <sub>3</sub>	2·344
H <sub>2</sub> O	2·102

100·000

The presence of phosphoric acid in the crystalline rocks has been noted by Sullivan.§ and by Fownes.|| The latter mentions its occurrence in basalt; in trachyte from Drachenfels; in lava; and in the porcelain clay of Dartmoor; and he attributes the fertility of soils derived from lavas, &c., in some measure to phosphoric acid, which, though comparatively small in quantity, yet in an extensive district of such rocks becomes an item of some importance.¶

The rock under notice is strictly a trachyte-porphry; and would

\* Watts' Dict. of Chem., vol. ii., p. 780.

† Syllabus of Course of Lectures. Mus. Irish. Ind. 1866.

‡ Jour. R. G. S. I., vol. ii. (New Series), part ii., p. 159.

§ Phil. Mag. (3) XXVII. p. 161.

|| Ann. Chem. Pharm. LX. p. 190.

¶ Phil. Trans. CXXV. p. 53, et seq.

be classed as a rhyolite by Von Cotta, after Von Richthofen; its specific gravity being low, and the proportion of  $\text{SiO}_2$ , above 67 per cent.\*

It is evident from the analysis that the Tardree trachyte is not in its original condition, but has been much altered by pseudomorphic action; and that the felspar, originally a normal orthoclase, is becoming slowly changed into one having more of the composition of a lime felspar. It is doubtful whether felspars are ever entirely converted in this way, although Bischof adduces some weak evidence on that head; but there is certainly here a transition in that direction.

From this arises the consideration of the geological age of the trachyte. The changes here pointed out must have taken place very slowly indeed, and as the analyses I have seen of trachytes of known tertiary age show little or no traces of subsequent alteration, I am inclined to think that this one dates its existence from a time much more remote than any of those. Unless it be supposed that in this instance the chemical reactions went on with more than ordinary rapidity, it would seem to be another proof that the more acidic rocks of the same kind are not always the most recent; nor that of basic and acidic igneous rocks of the same great period are the former always the elder.† On this theory of Richthofen the basalt of Antrim should be the most ancient of these two rocks, yet looking at analyses of Lower Miocene trachytes, they are seen to present little appearance of change, so that I should not be surprised to hear that this trachyte is much older than the basalt. I therefore hold with Delesse,‡ that the most silicated crystalline rocks of the same period are the oldest. Their being so is easily understood if we believe that at least a considerable portion of the quartz in crystalline rocks is the result of subsequent deposition from aqueous solution, which in many cases is highly probable.

IX.—ON THE ANALYSIS OF A LIMESTONE, COMPARED WITH THAT OF THE SAME ROCK WHERE IT IS IN CLOSE PROXIMITY TO A DOLERITIC DYKE. By EDWARD T. HARDMAN, Assoc. Roy. Coll. Sci., Ireland, F.R.G.S.I., of the Geological Survey of Ireland.

[Read June 14, 1871.]

At Enisheron, six miles north-east of Ballina, county Mayo, extending along the sea shore for some miles, are almost horizontal beds of an impure earthy limestone, belonging to the carboniferous period. The rock is of a dark bluish grey colour, moderately hard and compact, and contains very many silicified remains of *Zaphrentis cylindrica*, but has few other fossils, and these often composed of iron pyrites, of which

\* Rocks Classified and Described. B. Von Cotta, p. 187.

† See Rocks Classified, &c. Von Cotta, pp. 187 and 369.

‡ See Phil. Mag. (4) VI. p. 210.

the rock itself contains a small quantity. Several dykes of dolerite are seen running across the strike of the beds, but only near one of them does the limestone present any appearance of alteration. This dyke is about fifty yards wide; and at one side of it, where the junction is well seen, and for a distance of from nine to eighteen inches from it, the limestone has a remarkable aspect. It is almost white, of a very compact, but finely granular texture; its fracture is markedly conchoidal, and it is so hard that it cannot be scratched with the knife, but it effervesces freely with dilute hydric-chloride. It contains no iron pyrites, but instead a few small rhombohedral crystals of gypsum.\* A trilobite—*Phillipsia pustulata*, I think—was discovered in it by my friend and colleague, Mr. Symes.

I thought it worth while to make and compare analyses of the original and of the altered limestone.

The analyses were both done in the same way. The powdered rock, dried at  $100^{\circ}\text{C}$ ., was treated with dilute H Cl. In the solution the bases contained were estimated. The insoluble residue was dried, ignited, and weighed, then fused with potassic and sodic carbonates, and the silica, alumina, and ferric oxide which it contained estimated. In order to ascertain whether any calcium or magnesium might be combined in any other way than as carbonate, the carbonic anhydride in each portion was determined, and the proportion was almost exactly that required for combination. By the kind permission of Professor Galloway, the analyses were made in the laboratory of the Royal College of Science.

The following are the results :—

Quantity taken for analysis,	I. (Limestone). 24.20 grns.	II. (Altered Limestone). 17.675 grns.
Insoluble residue (after ignition),	3.25	8.40
Containing { Si O <sub>2</sub> Al <sup>2</sup> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	3.25 trace trace	6.14 2.14 0.16
Loss by ignition = Org. matter,	0.07	
Soluble portion,		
{ Ca CO <sub>3</sub> Mg. CO <sub>3</sub>	19.09 0.025	8.99 0.05
Containing { Al <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub> Fe O	1.64	0.165 trace
	24.075	17.605

For the estimation of the iron it was necessary to take fresh portions. These were :—

\* Sulphate of lime might be expected on account of the presence of iron pyrites in the unaltered portion. See "Bischof's Elements of Chem. and Phy. Geo.," vol. ii., p. 43.

I.			II.		
Amount taken,	24.20 grns.	36.295 grns.	Per cent.	11.32 grns.	Per cent.
Total Fe,	0.275		1.13	0.25	2.20
Fe as Fe O,		0.225	0.62	trace	
∴ Fe as Fe <sub>2</sub> O <sub>3</sub> ,			0.51		2.20
Fe <sub>2</sub> O <sub>3</sub> ,			0.72		3.14
Fe O,			0.79		

The percentage compositions are, therefore—

I.		II.
Si O <sub>2</sub> ,	13.45	34.74
Ca CO <sub>3</sub> ,	79.00	50.86
Mg CO <sub>3</sub> ,	0.10	0.20
Al <sub>2</sub> O <sub>3</sub> ,	6.09	10.86
Fe <sub>2</sub> O <sub>3</sub> ,	0.72	3.14
Fe O,	0.79	trace
Organic matter,	0.80	
	100.45	99.80
Sp. Gr.	2.778	2.523

The carbonic anhydride was determined by Fresenius and Wills' method:—

I.		II.
Amount taken,	19.978 grns.	22.005 grns.
Apparatus, with limestone, &c., =	2321.55 grns.	2313.28 grs.
„ after experiment, =	2314.60	2308.30
Loss = CO <sub>2</sub> ,	= 6.95	4.98
∴ per cent. CO <sub>2</sub>	= 34.84	22.65
79.00 Ca CO <sub>3</sub> contains	34.76 CO <sub>2</sub>	50.86 Ca CO <sub>3</sub> contains 22.37 CO <sub>2</sub>
0.10 Mg CO <sub>3</sub> „	0.05 „	0.20 Mg CO <sub>3</sub> „ 0.10 „
Percentage CO <sub>2</sub> required for } combination,	= 34.81	22.47
		Excess due to imperfect analysis = 0.18 per cent.

So that there can be no doubt that all the calcium and all the magnesium remaining in the altered part is combined as carbonate.

It will be seen that in the portion that has undergone alteration there is a great deficiency of carbonates, but although there seems to be also a difference in the amounts of the other constituents, this is more

apparent than real, and the absolute weights of these remain very nearly the same as in the original rock.

Assuming that the silica, alumina, and oxides of iron have not been much affected, as to quantity, by the transmuting agencies, the actual percentage of carbonates lost may be approximately arrived at in this way:\*

$$\text{Si O}_2 + \text{Al}_2 \text{O}_3 + \text{Fe}_2 \text{O}_3 + \text{Fe O in (I.)} = 21.05$$

$$\text{ " " " " (II.)} = 48.74$$

Carbs. in (I.)

$$\text{Then, as } 21.05 : 48.74 :: 79.10 : 183.15 = \text{carbs. in II. when unaltered.}$$

Substituting this for 51.06, in (II.),

$$\begin{array}{rcl} \text{Si O}_2 & = & 34.74 \\ \text{Ca CO}_3 \} & = & 183.15 \\ \text{Mg CO}_3 \} & & \\ \text{Al}_2 \text{O}_3 & = & 14.00 \\ \text{Fe}_2 \text{O}_3, \&c. \} & & \\ \hline & & 231.89 \end{array}$$

That is, 100 grns. of the now altered limestone would weigh 231.89 grns., if all the carbonates were replaced.

$$\text{Then } 183.15 - 51.06 = 132.09 = \text{loss in } 231.89 \text{ grns.}$$

$$\therefore \text{Loss per cent.} = 56.96.$$

Subtracting this from the percentage found in (I.), we get this composition:—

$$\begin{array}{rcl} \text{Si O}_2 & = & 13.45 \\ \text{Carbonates} & = & 22.14 \\ \text{Al}_2 \text{O}_3 & & 6.09 \\ \text{Fe}_2 \text{O}_3 & & 0.72 \\ \text{Fe O} & & 0.79 \\ \text{Org. Matter} & & 0.30 \\ \hline & & 43.49 \end{array}$$

The corresponding percentage of which is

$$\begin{array}{rcl} \text{Si O}_2 & 30.92 & \\ \text{Carbonates} & 50.90 & \\ \text{Al}_2 \text{O}_3 & 14.00 & \\ \text{Fe}_2 \text{O}_3 & 3.67 & = \left\{ \begin{array}{l} \text{Fe}_2 \text{O}_3 \quad 1.65 \\ \text{Fe O} = 1.81 = \text{Fe}_2 \text{O}_3 \quad 2.02 \end{array} \right. \\ \hline & 99.49 & \end{array}$$

If the removal of the carbonates had been the only alteration this

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\* I do not remember having seen the plan pursued in the present paper adopted in any other case. The usual way in which such comparative analyses are laid before the public is, to give both results side by side without any word of explanation. Consequently, an erroneous impression is often given as to the alteration that has occurred, especially so when, the paper being read, the hearers have little time to consider the question.

ought to represent the composition of the rock so modified. But it appears there is also a slight change in the proportions of silica and alumina, which was most probably caused by interchange between the constituents of the minerals forming the dyke and those of the limestone subsequent to the primary alteration. That the latter was due to the heat of an igneous mass there can be little question, for although on the same shore narrow dykes of the same dolerite are seen protruding through the limestone, any observed by me had no visible trace of alteration at their junctions. Whatever its composition or condition might be at the time, the matter forming the large dyke must have possessed sufficient heat to drive off a part of the carbonic anhydride, the calcic oxide being afterwards removed as hydrate. It is only where the mass is of such bulk as to have retained its heat for a considerable time that any transitional effect is seen on the enclosing rock. If the alteration were entirely due to aqueous causes, then we might reasonably expect to find a similar result near the smaller dykes.

X.—NOTE ON THE GEOLOGICAL FORMATION OF SOME OF THE TRIOXIDES.  
By CHARLES R. C. TICHBORNE, F.C.S., M.R.I.A., &c.

[Read June 14, 1871.]

IN a communication read before the Royal Irish Academy, in April, I brought forward some experiments upon the molecular dissociations, by heat, of compounds in solution. I therein dwelt particularly upon one natural group—the aluminic, chromic, and ferric oxides ( $Al_2^{III}O_3$ ,  $Cr_2^{III}O_3$ , and  $Fe_2^{III}O_3$ ). I therein demonstrated, for the first time, that the compound molecules of the first two of this group are dissociated by heat, like their analogue, the ferric oxide. Dissociation is well marked, as regards the ferric salts, by the change of colour exhibited on heating their solutions. All the ferric salts are nearly colourless, or possess a very faint tinge. Heat applied to their solutions gives an intense darkening, in ratio to the temperature employed. It is almost certain that the first action of heat is the dissociation of crystalloidal water, and then the splitting up of the structure into a basic salt and free hydrochloric acid; ultimately a basic precipitate is procured, the volume of water present determining the temperature at which this precipitate is deposited.

I find that the chromium trioxide behaves exactly in a similar manner, except that, *ceteris paribus*, the point of dissociation, or therm-analytic point, is higher. The change of colour observed on boiling the chromic salts (violet), which become green, is due to the basic condition of the salt. An ordinary solution of a chemically pure salt becomes more blue on the cautious addition of acid, simply because it is in the first instance in a slightly basic condition, from the action of the water of solution. In a similar manner, with the ferric salts, the most colourless solution is obtained by adding acid cautiously to a chemically neutral solution. If, however, we add to such a solution a

sufficient quantity of alkali to render it basic, but not to cause a precipitate, we obtain the same results as on boiling—that is to say, a basic solution evidenced by its green colour. By pouring a solution of any chromic salt into a large volume of boiling water, a basic precipitate will be procured, observable by a powerful light. Similar results will be got with the alumina salts, but in these molecules the thermanalytic point is still higher. At ordinary atmospheric pressure the precipitates are only observable whilst the solutions are at  $100^{\circ}\text{C}$ ., and the water must bear a relative volume of about 50,000 to 60,000 of water to 1 of the solid salt. They regain their original molecular construction on cooling. The lime or electric light is absolutely necessary to observe some of these precipitates. The introduction of another group of molecules capable of assimilating the stylious elements lowers the point of dissociation, and thus the alums of this group exhibit the phenomena detailed in a striking manner. The application of such inquiries to geology is self-evident; for it is in geological changes that water and the thermal force work so decidedly. Only the molecules dissociable at a temperature of  $100^{\circ}\text{C}$ . can be acted upon at the ordinary pressure in aqueous solutions; but with extraordinary pressure striking results are obtained; and thus anhydrous ferric oxide may be easily produced, with a pressure of nine to twelve atmospheres, from an aqueous solution of ferric chloride. In such a case the precipitated oxide does not recombine with the stylious molecule, simply from the well-known insolubility of these dehydrated molecules even in strong acids.

In speaking of  $\text{Fe}_2\text{O}_3$ , Dr. Percy, in his "Lectures on Chemical Geology," says:—"It is not volatile, and yet it may be a product of volatilization. The magnificent specular iron ore, for example, is a volcanic product, and it may be easily accounted for. Supposing we have the vapour of sesquichloride of iron, there is no difficulty in accounting for the formation of the sesquioxide of iron in volcanic regions. If that vapour be brought in contact with the vapour of water, we get a deposit of crystallized sesquioxide of iron with the formation of hydrochloric acid." Now, from actual experiment, I am prepared to go even further than Dr. Percy, and state that an oxide is procured on submitting any of the salts of iron to a comparatively limited pressure of ten to twelve atmospheres in the presence of water; and that this oxide resembles, both in its chemical and physical properties, the natural product. How easy is it to conceive the results obtainable with 200 or 300 atmospheres, and the increased range of temperature! The following experiment will illustrate this statement:—A solution of ferric chloride (the chloride is a little more sensitive to the dissociative influence of heat) was boiled until a basic salt was procured. The resulting precipitate was then placed in a German glass tube, and filled with water. This tube was left open at one end, and placed upright in an apparatus by which the surrounding water was kept boiling under pressure. The thermometer connected with this apparatus showed that the pressure ranged from eight to eleven atmospheres during the experiment, which lasted about four hours. When the tube was removed

the precipitate had entirely changed in character. The supernatant fluid still gave on testing a trace of iron, and a decided indication of hydrochloric acid, but almost all the iron was in the form of a dense oxide, exactly resembling specular iron ore. When examined by the microscope, it was found to consist of laminæ, having a black metallic lustre, when viewed by reflected light; but when the pieces were thin enough, they were seen to be brilliantly red by transmitted light.

A small quantity of this precipitate was collected, and after weighing was submitted to analysis by boiling with ammonia, washing, and igniting.

The original weight was 1.32 gramme.

After the experiment the weight was 1.282 gramme.

It is therefore self-evident that not only the stylvous element, but the water, had been sufficiently dissociated from the oxide in this instance to view it as an anhydrous product, although it had been produced in the presence of that body. All the iron molecules are capable of dissociation in a similar manner; the thermanalytic point, however, is not constant, but varies. Time and pressure are, of course, the important elements of change in all cases of dissociation, whilst, as increased dilution produces a more basic condition of the solution, it becomes to a certain extent equivalent to the increased range of temperature produced by pressure.

Somewhat similar remarks apply to the possible production in a like manner of corundum and its precious varieties. This is rendered more probable by their association with diaspore and other minerals. The remarks upon this subject I propose to reserve for a future communication.

XI.—REPLY TO THE OBSERVATIONS IN MR. KINAHAN'S PAPER "ON THE CARBONIFEROUS ROCKS OF IRELAND." By Professor EDWARD HULL, F. R. S. [Abstract].

[Read November 8th, 1871.]

THE author commenced by stating that the classification of the Carboniferous strata of the south and east of Ireland, in his paper on the Ballycastle coal-field,\* had been inserted simply for the purpose of showing the geological horizon of the coal-series of Ballycastle, as compared with that of the coal-series in Ireland generally; and not with any intention of questioning on that occasion the nomenclature adopted by the late Director of the Geological Survey and his associates.

Nevertheless, the question having now being raised, the author saw no good grounds for receding from the position he had maintained, viz:—that the series of black shales, with marine fossils, together with the overlying flagstones, which had been shown by the researches of the Geological Surveyors to overlie directly the Carboniferous Limestone of the south-west and south-east of Ireland, were the representatives of the "Upper Limestone Shale,"† and (possibly "Millstone Grit" of England), and ought not to be termed "coal-measures," as understood in England and Wales.

That this was the view entertained by Professor Jukes himself, the author regarded as evident, from the following passage occurring in a note to the "Explanation of Sheet 137 of the Geological Survey Maps," drawn up by Messrs. Jukes and Kinahan (1859):—"If we were to seek to force this coal-measure series into strict analogy with those of other districts, we might perhaps look upon these lower black-shales, with marine fossils, as the representatives of the upper limestone shale of Derbyshire; and the set of sandstones and flagstones, No. 2, as the representative of the Millstone Grit of that country. It would, however, be impossible in the south of Ireland to draw any recognisable boundaries subdividing the coal-measure series, and the attempt would only therefore tend to confusion. Doubtless, the whole of the coal-measure series of central Ireland is contemporaneous with the lower part only of that of central England, *including the Millstone Grit in that lower part*" (p. 11). Therefore, from the above passage it was clear to the author that the reason of Mr. Jukes for applying the term "coal-measures" to that series of shales and sandstones overlying the lime-

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\* "On the Geological age of the Ballycastle coal-field," Trans. Royal Geol. Soc. Ireland, 1871.

† The Upper Limestone Shale, together with a series of sandstones and shales lying below the "Kinder Scout Grit" of the north of England, are now included in the series of the "Yoredale Rocks" by the Geological Surveyors. In Yorkshire and Lancashire these beds attain a thickness of 2000 to 4000 feet.

stone was the difficulty of drawing any boundary lines between the beds in the south of Ireland, owing to the physical structure of the country; while at the same time he recognised the true position of these beds as compared with the English series.\*

While, therefore, the author had no doubt in his own mind that, on stratigraphical grounds, the black shale series of the south of Ireland, overlying the Carboniferous limestone, ought to be regarded as the true representative of the upper limestone shale (or Yoredale beds) of England, he was ready to modify his classification (as given in the paper previously quoted), to the extent of admitting the probability of the "Flagstone series" being the representative of the Millstone grit; in which case the overlying beds with coal would be the representative of the "Lower coal-measures" (or Gannister Beds) of England, as defined by the Geological Survey of Great Britain (see Index Sheet of Colours of formations of Geological Survey, Great Britain; also "The Geology of the Carboniferous limestone, &c., of North Derbyshire and parts of Yorkshire," Mem. Geol. Survey, 1869). This view the author believes would be quite in harmony with that held by Professor Jukes, Professor Phillips, and many other geologists; and would also be found in accordance with analogy and observation.

In accordance with the above views, the author ventured to offer the following as the representative series in the north and centre of England, and in the south and east of Ireland; which, it will be observed, is a slight modification of the classification as referring to the east of Ireland, given in his paper "On the Geological age of the Ballycastle coal-field."

*Tabular view of Representative Members of the Carboniferous System of England and the south of Ireland.*

ENGLAND (NORTH).		IRELAND (SOUTH).	
	feet.		
4. Coal-measures.	c. Upper Coal-measures,	2000	c. Absent.
	b. Middle, with thick coal-seams, . . . . .	3000	b. Absent; or slightly represented in lower part.
	a. Lower Coal-measures with thin coals and marine fossils ( <i>Goniatites</i> and <i>Aviculo-pecten</i> ),	2000	a. Coal-measures of Cork, Limerick, Kilkenny, &c. (lower beds).
3. Millstone Grit.	{ Grits and Shales with plants and marine fossil shells; from 2000 to	3000	3. Flagstone series, 700.

\* Professor Phillips says—"The great area of the Irish Carboniferous system unfortunately yields but little coal, the upper, and more generally productive portion (e) being only perhaps recognisable about Dungannon and Ballycastle: most of the coal . . . . . near Kilkenny and Newcastle is of the age of the Millstone grit (b), or the lowest part of (e), i. e. the coal-series above the Millstone grit."—Manual of Geology, p. 206 (1855).

2. Yoredale Beds, or Upper Limestone Shale.	{ Shales, flags and grits, black shales and lime- stones in lower part, with marine fossils; <i>Goniatites</i> , <i>Orthoceras</i> , <i>Avicula-pecten</i> , &c., from 2000 to	3000	2. Black shale series with marine fossils, abun- dant,	800
	1. Carboniferous limestone.		1. Carboniferous Limestone.	

XII.—ON PHANEROPLEURON ANDERSONI (HUXLEY), AND URONEMUS LOBATUS (AGASSIZ). By RAMSAY H. TRAQUAIR, M. D., M. R. I. A.; Professor of Zoology in the Royal College of Science, Dublin. (Plate V.)

[Read December 6, 1871].

I.—*Phaneropleuron Andersoni* (Huxley).

THE genus *Phaneropleuron* was instituted by Professor Huxley, in 1859,\* for the reception of that singular fish *P. Andersoni*, from the Upper Devonian Yellow Sandstone of Dura Den, in Fifeshire, which species was also subsequently described by him in the Tenth Decade of the Geological Survey, published in 1861. In the present communication I have a few notes to contribute regarding the general characters of this interesting Devonian form, the result of a careful examination of the specimens in the St. Andrew's Museum, obtained subsequently to the publication of Professor Huxley's descriptions†. I shall also take the opportunity of describing an apparently very closely allied Carboniferous fish, the *Uronemus lobatus* of Agassiz, a species named, but not figured by that eminent naturalist, and which can also hardly be said to have been described by him.

As Professor Huxley has pointed out in his excellent and concise descriptions above referred to, *Phaneropleuron Andersoni* is remarkable for its thin circular overlapping scales, for its persistent notochord but well ossified neural and hæmal arches, spines, and median fin-supports, and for the great length and prominence of the ribs, which shine so conspicuously through the thin external covering of scales. The ventral, and most probably also the pectoral fins, are acutely lobate, with a central scaly axis fringed with rays on both sides, as in the recent *Ceratodus Forsteri*, the extinct *Holoptychius*, &c.; and there is a distinct narrow anal fin in front of the lower lobe of the caudal. The dorsal fin commences low in front, but becomes deep and broad as the

\* In Anderson's "Dura Den," a monograph of the Yellow Sandstone. Edinburgh, 1859.

† My best thanks are due to the Literary and Philosophical Society of St. Andrew's, for the free permission which they accorded to me to examine and take notes of the specimens referred to in the text.

form of the body narrows towards the tail. As regards the form of the tail and the relations and configuration of the dorsal fin behind. Professor Huxley's views, at the time he wrote his descriptions, were that the dorsal terminated posteriorly in an almost vertically truncated extremity, beyond which the notochord was continued for some distance. The upper lobe of the caudal seemed to be obsolete, while on the other hand he could trace the lower lobe, commencing immediately behind the anal to near the extreme end of the body.\* Subsequently obtained material, however, shows that the appearances which justified so eminent a palæontologist in adopting the above-mentioned views, were due to defective preservation of the specimens at his disposal, and that the dorsal fin was, as in the recent *Lepidosiren* and *Ceratodus*, continued as a *dorso-caudal* to the very extremity of the body, which condition I have endeavoured to express in the subjoined woodcut, representing a restored outline of the fish. I may mention that



Professor Huxley has expressed to me his entire concurrence in this view. The tail of *Phaneropleuron* is then beautifully diphyccercal, a slight tendency to the heterocercal form being, however, shown by a very constant, though slight, upward curvature of the caudal extremity of the body.

I am also in a position to give a few additional details regarding the structure of the head, though unfortunately our knowledge on this point still remains very imperfect. In general configuration the head must have resembled much that of *Ceratodus Forsteri*, being considerably flattened above, while the high occipital region slopes off downwards and forwards to the bluntly-pointed muzzle. Internally the cranium seems to have been very extensively cartilaginous, as I have seen no trace of any ossifications of its base or side-walls; but above, it was protected by a buckler formed of a great many osseous plates firmly articulated together by suture, though none of the specimens I have seen are sufficiently perfect to enable one to map out completely their number and arrangement. However, in two of the specimens in the St. Andrew's Museum, three plates, one median, and two lateral, may be very distinctly made out, forming the posterior or nuchal margin of the cranial shield, and corresponding to the three similar plates in

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\* Mem. Geol. Survey: Decade X., page 49. Also in Anderson's "Dura Den," page 67.

*Glyptolæmus*. In front of the median plate are two elongated *parietals*, while on each side of it, and articulating also with the posterior external angle of the corresponding parietal, is another pretty large bony piece (*squamosal*?). Between the latter and the external margin of the buckler is a row of smaller plates, of which three are evident enough; but in no specimen I have seen can the arrangement of the plates in front of those described be definitely made out, nor can I settle the question as to the position of the nasal openings. I have seen no *hyomandibular*; but in two specimens, one in St. Andrew's, the other in the British Museum, a stout *palato-pterygoid* may be seen to extend from near the articular extremity of the lower jaw forward towards the snout: posteriorly the surface of this bony lamina slopes upwards and inwards, but in front it becomes nearly horizontal, and there it is seen to be armed on its oral surface with numerous conical teeth. The form of the maxillary and pre-maxillary bones is not determinable, but the upper margin of the mouth was evidently bordered by dentigerous bones, the teeth being as described by Professor Huxley, in one row, short, conical, and pointed. The lower jaw is stout, composed evidently of several pieces, and close to the symphysis, the ramus makes a pretty sharp bend horizontally inward, to meet its fellow. It is armed also with pointed teeth, an especially large one being seen at the symphyseal angle referred to. The *operculum* is very large, rounded posteriorly and inferiorly, but with nearly straight superior and anterior margins; below, it overlaps an antero-posteriorly elongated, somewhat ovate *suboperculum* not before noticed. There is no trace of any *preoperculum*. The orbit seems to have been situated rather far back; a curved bony plate is seen on the cheek, separating it from the operculum, and bounding it below and behind. Regarding the under surface of the head, I have nothing to add to Professor Huxley's description, not having seen any better specimen than that in the British Museum, to which he refers, and which certainly shows that the space between the rami of the lower jaw was occupied by bony plates, whatever their number might have been. Of the bones of the shoulder-girdle, I have only seen two, viz., a well-marked *clavicle*, and at least one *supra-clavicular* proceeding from it towards the occipital region of the skull.

## II.—*Uronemus lobatus* (*Agassiz*).

Some time ago, while looking through the Carboniferous fishes in the collection of the late Mr. Hugh Miller, my attention was directed by Mr. C. W. Peach, who was with me on that occasion, to certain unnamed specimens, which, though smaller in size, bore an unmistakable resemblance to the *Phaneropleuron* of the Dura Den Yellow Sandstone. They were imbedded in a stone identical in mineral character with the well-known Lower Carboniferous Limestone of Burdiehouse, near Edinburgh; and any doubts as to their having been derived from that locality were sufficiently dissipated, by the fact of two additional specimens of the same fish having been also found by that most inde-

fatigable and successful collector, Mr. Peach, in the quarries of the same locality. I am indebted to Mr. Archer, the able and liberal minded Director of the Edinburgh Museum of Science and Art, for permission to describe the three specimens in the Miller collection, and also to my genial friend Mr. Peach, both for originally directing my attention to the subject, and for the loan of the two specimens in his private cabinet.

These five specimens, the first which I had seen of this interesting Carboniferous fish, may be enumerated and characterised as follows :—

No. 1. Specimen (Fig. 1, Pl. V.), measuring  $5\frac{1}{2}$  inches in length, and showing the head, body, and caudal region, except the extreme termination of the tail. In the Miller collection, Edinburgh Museum of Science and Art.

No. 2. Specimen (Fig. 2, Pl. V.),  $4\frac{1}{2}$  inches in length, without head, but showing the greater part of the abdominal region, with the tail up to its very termination. Miller collection.

No. 3. Portion of a fish evidently originally a larger specimen than either of the two preceding. It shows a large portion both of the abdominal and caudal regions, but without either the head or the point of the tail. Length,  $4\frac{1}{2}$  inches. Miller collection.

No. 4. A nearly entire specimen,  $5\frac{1}{2}$  inches long, somewhat distorted, showing a portion of the head, and also the extreme termination of the tail as in No. 2. In the collection of Mr. Peach.

No. 5. Portion of the caudal region, but without its extreme termination. Length,  $3\frac{7}{8}$  inches. In Mr. Peach's collection.

*Scales.* The body was evidently covered, as in the case of *Phaneropleuron Andersoni*, with thin and feebly ossified scales, which do not in any case conceal the bones of the prominent internal skeleton. Their exact size and configuration can hardly be accurately distinguished, owing to the state of preservation of the fossils, in which the scales are squeezed together into almost an homogeneous-looking film. As far as I can make out, they seem to have been of moderate size, cycloidal or somewhat rhombo-cycloidal in shape, imbricating in arrangement, and marked with concentric lines, but more especially with fine thread-like longitudinal or slightly radiating striæ.

*Head.* In specimen No. 1 the head measures  $1\frac{1}{2}$  inch in length, and is contained  $5\frac{3}{4}$  times in the length of the whole specimen as preserved, but the end of the tail being lost, the original proportion would probably be, at least, as 1 to  $6\frac{1}{2}$ . In front, a portion of bone is seen bearing a smooth, conical, sharp, tooth-like projection,  $\frac{1}{10}$  of an inch long. In No. 3 the impression of a large broad operculum is distinctly visible, but in neither of the specimens can the contour of any other of the bones of the head be distinguished, though in places it may be seen that their free surfaces were ornamented with fine ridges.

*Body.*—In general form the body must have considerably resembled that of *Protopterus*, being moderately broad in the abdominal region, and becoming gradually attenuated to a fine point in the caudal, but in specimens free from distortion a very distinct upward curvature of



Western Province

R.H. Baquar del. ad loc. C.H. Ford.



the axis of the body is seen near the tail. There being no traces of vertebral bodies visible, the notochord must have been persistent, and the empty space which it occupied is well seen, especially in the caudal region. The neural arches and spines are well ossified; the latter are slender in form, and are long in front, getting gradually shorter as we proceed backwards. The form of the neural spines is most distinctly seen in the caudal region, where each, springing from a slightly expanded neural arch, passes very obliquely upwards and backwards, and becoming thin in the middle, ends in a laterally flattened, expanded termination, to which one of the next set of elements, the dorsal fin-supports, may in many instances be clearly seen to have been articulated: indeed, I believe that this must always have been the case, though in the present fossils these elements are often displaced from each other, as in Fig. 2, Pl. V. These succeeding elements, the dorsal "interspinous bones," or fin-supports, well shown both in Figs. 1 and 2 of the Plate, are likewise slender in form, expanded at both ends, and pass, like the neural spines which support them, obliquely upwards and backwards. They are frequently slightly curved, with a forwardly directed concavity. They are rather short and delicate in front, attaining the greatest length and stoutness opposite the beginning of the caudal region, whence backwards they again become smaller, till towards the end of the tail they can no longer be distinguished from the neural spines. The ribs are, as in *Phaneropleuron Andersoni*, very long and prominent, and are well seen in Fig. 1. The hæmal spines follow on the ribs as we pass from the abdominal to the caudal region, and with the appended supporting bones of the anal and inferior lobe of the caudal fins, agree essentially with the corresponding elements on the neural side of the notochord. The ribs, neural, and hæmal spines, and median fin-supports seem to have been hollow, the central cavities, originally occupied by cartilage, being now filled with carbonate of lime.

*Fins.*—A comparison of the five specimens under examination shows that the dorsal fin was, as in *Phaneropleuron Andersoni*, and in the recent *Lepidosiren*, perfectly continuous with the upper lobe of the caudal. In specimen No. 1 (Fig. 1, Pl. V.), the dorsal is seen distinctly to commence only three-quarters of an inch behind the head. This dorso-caudal fin is low at its commencement, but gets broader posteriorly, attaining its greatest breadth opposite the beginning of the caudal region, after which it becomes rapidly attenuated as it proceeds to the tip of the tail. On the hæmal aspect of the body the evidences of a distinct anal fin are somewhat doubtful, though in No. 5 there are some appearances, which may be thus interpreted. The lower lobe of the caudal is not so broad as the upper lobe, and proportionally is considerably less deep than the corresponding part in *Phaneropleuron Andersoni*; like the upper lobe it becomes finely attenuated posteriorly. The tail thus formed is beautifully diphycecal, as seen in Fig. 2; there being, however, as above remarked, a slight upward curvature of the axis of the body at its caudal extremity.

This curvature is not seen in Fig. 2, as the specimen has undergone a slight distortion, but it may be observed in Fig. 1, and is still better seen in specimen No. 5, not figured.

The rays of the median fins are very fine, frequently bifurcating at their tips, and spring in bundles, which may be best studied in the dorso-caudal. They have, in fact, the same structure as in *Phaneropleuron Andersoni*. Each bundle results from the division, into numerous raylets, of the distally-directed apex of a small triangular basal piece, which, proximally, may frequently be seen to be articulated to the subjacent extremity of an interspinous bone or fin-support. A few of these triangular bases of the dorso-caudal fin-rays may be seen both in Figs. 1 and 2, though they are considerably more distinct in specimens Nos. 3 and 5, not figured.

In specimen No. 1 (Fig. 1, Pl. V.), a bone of the shoulder girdle, probably the clavicle of the right side, is seen, but no undoubted trace of the pectoral or ventral fins can be detected in any of the fossils.

Between the above described Carboniferous fish, and the *Phaneropleuron* of Dura Den, the resemblances are sufficiently apparent, notwithstanding the want of detail regarding the structure of the head, and the condition of the pectoral, ventral and anal fins. Accordingly, at the meeting of the British Association at Edinburgh, in August, 1871, I described the specimens referred to as a Carboniferous *Phaneropleuron*, under the name of *Ph. elegans*. Subsequently, however, to the publication of my description,\* the Earl of Enniskillen and Sir Philip Egerton were each kind enough to send me for comparison a specimen, from their respective collections, of the Burdiehouse fish, long ago named by Agassiz *Uronemus lobatus*, and which proved to be identical with my *Phaneropleuron elegans*. *Uronemus lobatus* was catalogued by Agassiz as one of his family of Coelacanthi,† but was not figured, and can hardly be said to have been described by him, as he gives no detail concerning it. I may, therefore, quote his entire description in full. "Le genre *Uronemus* se distingue par sa longue dorsale qui commence presque à la nuque, et se continue sans interruption jusque à la caudale; l'anale n'est pas non plus séparée de la caudale. Ce genre ne renferme que de petits poissons de l'époque houillère. J'en connais assez bien une espèce du calcaire de Burdiehouse, à laquelle j'ai donné le nom d'*Uronemus lobatus*."‡

Professor Huxley, in his well-known Essay on the classification of the Devonian Fishes, states that he had not seen *Uronemus*, and, as no details concerning it were given by Agassiz, leaves the question open as to whether it belongs to the family of *Coelacanthini* as defined and limited by himself.§ But the specimens which I have described show

\* Geol. Magasine, Vol. VIII., pp. 531-535. December, 1871.

† Poissons Fossiles, Vol. II., Part II., page 180.

‡ Ibid., page 178.

§ Dec. Geo. Survey, X. p. 20.

that *Uronemus* is not a Coelacanth in the modern acceptation of the term but belongs to the family of Phaneropleurini, being closely allied to, if not generally identical with, the *Phaneropleuron* of Dura Den. I must, however, own that the Burdiehouse specimens are sufficiently imperfect as to detail of head, and as to the condition of the anal fin, as to render it very possible that better specimens may subsequently demonstrate decided generic distinctions between it and *Phaneropleuron Andersoni*. If Agassiz is right in stating that the anal fin is confluent with the lower lobe of the caudal, then, of course the distinction is obvious enough, but as to this point I have never been able perfectly to satisfy myself. Under these circumstances, I must consider it better that the Dura Den and Burdiehouse fishes should in the meantime remain under the names originally bestowed on them, and am therefore ready to withdraw the name of *Phaneropleuron elegans*, which I had applied to the latter.

Lord Enniskillen's specimen is  $4\frac{1}{2}$  inches long, and shows the head, though the extreme end of the tail is wanting. At the very tip of the apparent snout is seen the impression of a small portion of bone, whose edge must have been set with a row of small pointed teeth, these also being only seen in impression. About  $\frac{3}{4}$  inch back from the end of the snout, and in the middle of the confused and unreadable mass of bony matter representing the head, are distinctly seen several conical, smooth, tooth-like bodies,  $\frac{1}{4}$  inch in length, and existing apparently in an upper and lower opposing set. The upper set are evidently palatal; the lower may appertain to the lower jaw. Possibly they may be denticulations of ctenodont plates, but from the state of preservation of the head, it is hardly possible to say so with certainty. The specimen is rather injured on the hæmal aspect of the caudal region, so that no additional information regarding the anal fin is gained from it, nor from the other specimen in the cabinet of Sir Philip Egerton. The latter specimen measures  $3\frac{1}{2}$  inches in length; the head and anterior part of the trunk are wanting, but the tail is shown to very nearly its termination. The greater part of the dorso-caudal fin is well seen, but the lower lobe of the caudal is rather deficiently exhibited. This specimen, however, shows a well-marked, narrow, lanceolate ventral fin, one inch long and  $\frac{3}{8}$  inch broad at its middle. Its state of preservation is unfortunately not sufficiently good to enable one with accuracy to recognise its exact structure; a few fine rays at some parts being all that is definitely seen;—the general aspect is, however, that of an acutely lobate member.

#### EXPLANATION OF PLATE V.

FIG. 1. *Uronemus lobatus*, Ag., natural size, from the Lower Carboniferous Limestone of Burdiehouse.

FIG. 2. Another specimen, natural size, without the head, but showing the extreme tip of the tail. The dorso-caudal fin is injured in front, and the direction of the caudal axis slightly distorted, so as to spoil the beautiful, though gentle, upward curvature which in the other specimens it is seen to have towards its termination.

XIII.—ADDITIONAL NOTES ON THE FOSSIL FLORA OF IRELAND. ON  
*Filicites plumiformis*, n. s., BAILY, FROM THE CARBONIFEROUS LIME-  
 STONE NEAR WEXFORD. By WM. HELLIER BAILY, F.L.S., G.S.,  
 &c. (Plate VI.)

[Read December 6, 1871.]

THE fossil plant I have now to describe is of a very unusual character, when compared with those from the Coal shales or Carboniferous strata generally, having a considerable resemblance to some forms of Palæozamia, belonging to the Cycadææ, as well as to some of the Coniferæ.

Its most conspicuous characters are a series of elongated, linear, alternating leaflets, closely approximate, and arranged upon a central stem at an angle of about 12°; these leaflets are about three-quarters of an inch in length, and half a line in breadth, having a venation parallel to their axis, agreeing in respect of its not being branched with that of the Cycadææ. The central stem or rachis is regularly marked by closely set rows of three tubercles on the diameter exposed.

I have named the species *Filicites plumiformis* from its feather-like appearance, placing it in the ambiguous genus *Filicites* until more information can be obtained respecting it, or allied forms.

It approaches very closely in form to *Filicites vittarioides*, Brongniart,\* from the coal formation of Richmond, Virginia.

The specimens of this species in the collection of the Geological Survey of Ireland were obtained by the late Mr. Charles Galvan, from dark grey shale of the Carboniferous Limestone, at Whitestone, Quarry, near Drinagh, Wexford.

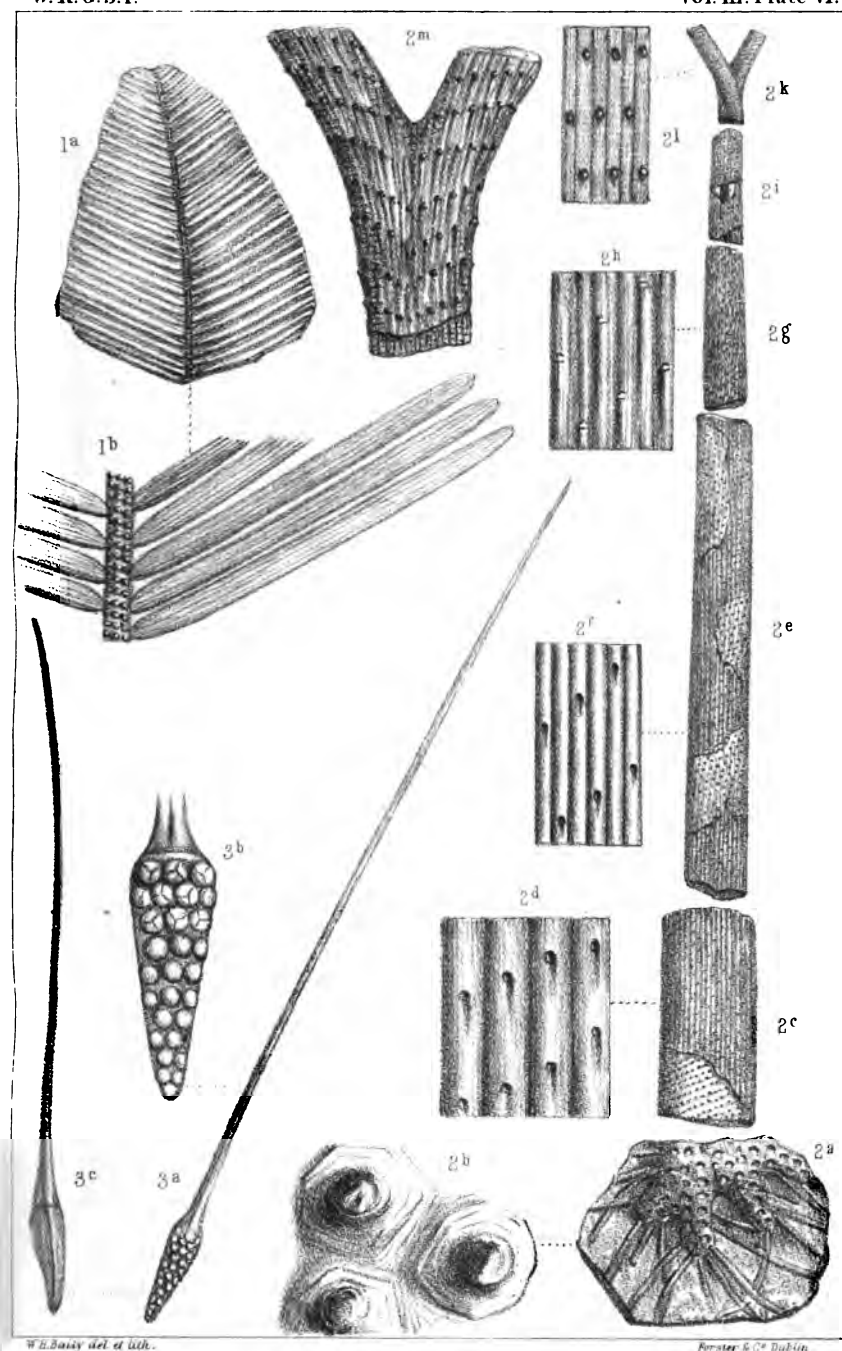
I wish also to bring before the notice of the meeting the results, up to the present time, of examinations of the collections made on several occasions at the very interesting and important fossil locality in Upper Old Red Sandstone, at Kiltorcan, Co. Kilkenny, the fossils from which place having excited considerable attention, especially from Continental and American Botanists.

The first to name some of these fossils, from specimens collected by the Geological Survey, was the late Professor Edward Forbes, at the Belfast meeting of the British Association, in 1852, who gave a brief description of the most prevalent form of the fossil plants, referring it provisionally to the genus *Cyclopteris*, under the name of *Cyclopteris Hibernicus*; he also named the large bivalve shell which accompanied it *Anodonta Jukesii*.

A selection of the plants from this place was afterwards submitted

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\* Histoire des Végétaux Fossiles, p. 391, Pl. CXXXVII., Fig. 1.



W. E. Bailey del. et lith.

Forster &amp; Co. Dublin.

Fig 1 a - b. *FILICITES PLUMOSUS*. (Bailey) CARBONIFEROUS LIMESTONE.  
 2 a - m. *KNORRIA BAILYANA*. (Schimper) UPPER OLD RED SANDSTONE.  
 3 a - c. " " ? SCALES OF FRUIT D?



to the celebrated French Naturalist, Mons. Adolphe Brongniart,\* who referred the plant named by Forbes *Cyclopteris Hibernicus* to *Adiantites*, on the ground of its possessing distinctive characters, including that of an intermediate pair of pinnules springing directly from the principal rachis, between the large lateral pinnules. Examples in fructification were afterwards discovered, having first been noticed from specimens in the collection of Mr. H. T. Humphreys: on this subject I read a Paper at the British Association at Leeds, in 1858, illustrated by specimens in the Geological Survey collection, describing the mode of fructification. Other examples of this species were also exhibited, having the base of the frond preserved.

This fossil Fern has since been included by Dr. W. P. Schimper, in his genus *Palæopteris*,† as being the most ancient of its type, that eminent authority stating that it differs from *Cyclopteris* in the arrangement of its leaflets, and from *Adiantites* in its mode of fructification.

At the British Association meeting at Aberdeen, in 1859, I described a new fossil Fern from the same locality, naming it *Sphenopteris Hookeri*, and offering some remarks upon the fish remains and associated fossils.

The British Association, on my application, made a grant of £20 on two occasions to assist in defraying the cost of excavations at the quarry from whence these fossils were obtained. In my first report, dated August 20th, 1869, I recorded another new species of *Sphenopteris*, *S. Humphresianum*, differing from *S. Hookeri*, and first observed by me to be a distinct species in the collection of Mr. Humphreys. In the second report to the British Association, September 17th, 1870, I recorded the discovery of a shrimp-like form of Crustacea, named by me *Proricaris Mac Henrii*, with additional plant and fish remains. In these reports I also alluded to the large and closely fluted stems which I had regarded as identical with *Sagenaria Veltheimiana* (previously named by authors *Sigillaria*), and which were associated with cone-shaped fruit (Plate VI., Fig. 2a - m.)

Professor Schimper, however, to whom the specimens were submitted, on his examination of the Survey Collection, and that of a series sent to him from the duplicates of that collection, having had a better opportunity of comparing it with the organs of fructification in *Sagenaria Veltheimiana* (which I had never seen), considering it to be distinct from that species, and a new form, did me the honour to name it after me—*Knorria Bailyana*. The upper branches of this plant I believe to be *Lepidodendron* or *Cyclostigma minuta* of Dr. Haughton; the root resembles *Stigmara ficoides* of Carboniferous strata, but differs in several respects from that common coal-measure fossil. The supposed fruit, of which we have obtained remarkably fine specimens, is a cone-like body, as in *Lepidodendron* and *Sagenaria*, composed of imbricated scales,

\* Journal Royal Dublin Society, Vol. i., p. 313 (1857).

† *Traité Paléontologie Végétale*, Vol. i., p. 475, Pl. XXXVI.

some of the detached ones showing large and very distinct sporules at their base, to which are appended long grass-like or linear leaves. Dr. Schimper remarks that "it differs from *S. Veltheimiana*, the fruit of which have the scales somewhat short and spatulated, whilst in our species the scales are extremely large and nearly subulated. In some specimens he had observed very large and distinct sporules at the basis of the scales, no other species of *Lepidodendron*, of which the fruits are known, having such large sporules—a proof, as he considered, of the inferiority of the plant, which was probably the oldest of the family."

The genus *Cyclostigma* was established by Professor Haughton in 1859, to include some other plants obtained from the locality already mentioned:\* of these, he enumerates three species, viz.:—*C. Kiltorkense*, *C. minutum*, and *C. Griffithii*. I believe it will be found, however, that *C. Kiltorkense* and *C. Griffithii* are varieties of the same plant, and that *C. minutum*, as before remarked, is the upper branches of *Knorria Bailyana*. I think it also very probable that *Lepidodendron Griffithii* of A. Brongniart is the terminal branch of *Cyclostigma Kiltorkense* (to which I would propose to refer these varieties). I differ with Mr. Wm. Carruthers (who spent a short time in looking over this collection with me, and to whom I also sent specimens for the British Museum) as to its identity with *Knorria Bailyana*,† its characters being, in my opinion, remarkably distinct: there is no fluting of the stem, the surface is finely striated, and the stigmata arranged at much greater proportionate distances from each other; moreover, it is generally found to occur in distinct beds to that of the *Knorria*, the layers often exhibiting a considerable mass of these plants compressed, one upon the other, although some specimens clearly show the original cylindrical form. Mr. Carruthers is therefore wrong in his statement in the article before cited, that "the genus *Cyclostigma* was founded on insufficient grounds;" and that "it was, in fact, founded on fragments of the bark of *Lepidodendron Griffithii* (Brongniart), to which species the *Lepidodendron* indicated by Professor Heer as *L. Veltheimianum* really belonged;" for, as I have shown, the characters of the *Cyclostigma* clearly entitle it to be considered as a distinct plant from the *Knorria* in question; and although the plant named *Lepidodendron Griffithii* by Brongniart (the original specimen of which is in the collection of the Royal Dublin Society) may very possibly be the terminal branch of *Cyclostigma*, as previously mentioned, I consider Mr. Carruthers, in his efforts to throw blame upon "Irish Palæontologists," is also wrong in declaring its identity with the *Knorria Veltheimiana* or *Bailyana* of Schimper, thus adding to the list

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\* Journal Royal Dublin Society, Vol. VII, p. 209, &c.

† As reported in the discussion on Professor Heer's Paper on the Carboniferous Flora of Bear Island, lat. 74° 30' N. See Quart. Jour. Geol. Soc. of London, Vol. xxxvii., Part I., pp. 1, &c.

of synonyms he has stated this plant to have received from various authors.

After the lapse of years, Fossil Botany, like other branches of science, has necessarily improved in classification: it is therefore no extraordinary occurrence that *Lepidodendron* should become *Sagenaria*, and both *Knorria*. The array of synonyms brought forward by Mr. Carruthers has therefore but little signification.

Professor Heer, in the Paper before referred to, considered the fossil plants of Bear Island to present a close resemblance to those of Tallow Bridge and Kiltorcan (specimens from both these localities having been sent to him by me, on behalf of the Geological Survey, for comparison), referring this flora to a set of beds which he denominated the "Ursa stage" of the Lower Carboniferous. The presence of fishes of Old Red Sandstone type, some genera being exclusively Devonian, as confirmed by Sir C. Lyell's remarks in the discussion on Professor Heer's Paper, still inclines me to the belief, as expressed in my previous remarks, that these beds of Kiltorcan are correctly referred to the Upper Old Red Sandstone.

In addition to the interesting plants from this locality, fish remains, referred by me to *Coccosteus*, *Dendrodus*, *Glyptolepis*, and *Pterichthys*, and of Crustacea, *Pterygotus Hibernicus*, *Eurypterus Kiltorkensis*, and *Proricharion Mac Henrii*, have been recorded in Papers read by me before the British Association.

#### XIV.—NOTES ON THE WHITE MARBLE QUARRIES OF CARRARA, ITALY.

By PROFESSOR EDWARD HULL, M. A., F. R. S., Director of the Geological Survey of Ireland.

[Read January 10, 1872.]

IN Autumn last (1871), I had an opportunity of visiting the far-famed quarries of Carrara, and of examining the structure of the valley of Torano, which runs up into the heart of the serrated ridges of the "Apuan Alps," the name by which this portion of the Apennines is known. I do not pretend to be able to add anything of importance to the investigations of geologists who have already very ably described the crystalline limestones and associated strata of the range overlooking the Bay of La Spezia, and fully established their geological relations; but the subject may not prove uninteresting to those who have not had the same opportunities as myself of visiting the quarries from which is derived nearly all the statuary marble at present in use in Britain, the Continent, and even America.

The crystalline limestones of the Apuan Alps have been the object of investigation by MM. Savi, Boué, Pareto, Guidoni, De la Beche, Pilla, and Murchison. Professor Savi in his memoir "Considerazioni

sulla struttura geologica delle Montagne Pietre Santine"\* pointed out that the Apuan Alps present in the succession of their mineral masses the same general features as those of the Pisan Hills, which are fossiliferous. But long before this (1830), Sir H. de la Beche had suggested from an examination of the fossils in the limestones at La Spezia that they were of Oolitic (Jurassic) age,† and this British geologist must be considered as having been the first to refer to their true geological age this celebrated group of rocks. Further investigations enabled Professor Pilla‡ to show that the crystalline limestones and schists of Carrara, Massa and Serravezza, gradually pass by changes in colour and crystalline structure into the dark blue and grey limestones and shales of the valley of the Tecchia, which, considered on a large scale, may be regarded as forming the lower portion of Jura-liassic series, representing in our own country the Lower Oolite and Lias. These views received at a shortly later date (1847-8), the concurrence and corroboration of Sir Roderick Murchison, who, in his elaborate paper "On the Geological structure of the Alps, Apennines and Carpathians," fully discusses the relations of these rocks with those of other parts of Europe, in that masterly and comprehensive manner so characteristic of the works of that eminent observer.§

*Geological series of formations.* The lowest and oldest formation in this part of the Apennines is the conglomerate known by the local name of *Verrucano*. In the absence of fossils its age is indeterminate; some geologists, like Professor Pilla, regarding it as Palæozoic; others, like the Marquis Pareto, regarding it as Trias; and others, with M. Collegno, viewing it as the base of the Liassic series.

Upon the Verrucano repose shales and limestones, including the mottled "Bardiglio" and other marbles; these beds are fossiliferous, and referrible to the period of the Lias and Lower Oolite, and are at the same time traversed by planes of slaty cleavage which admit of their being worked for roofing purposes; to these beds the white and grey crystalline marbles of Carrara, Massa, and Serravessa are referrible. Over these are massive buttresses of cavernous "rauch-kalk," in parts graduating into dark dolomite, forming picturesque peaks. On the eastern side of the range this massive buttress of dolomite is irregularly overlapped by lighter-coloured limestones with flints, probably the representatives of the Neocomian limestones, which in their turn throw off macigno sandstones and other rocks, referrible to the Lower Tertiary epoch.¶

Having thus presented a summary of the succession of the groups

\* Pisa, 1847.

† These fossils consist of species of *Orthoceras*, *Ammonites*, and *Belemnites*, "On the Geology of the Shores of the Gulf of La Spezia." *Proc. Geol. Soc. London*, Vol. I., 164-7.

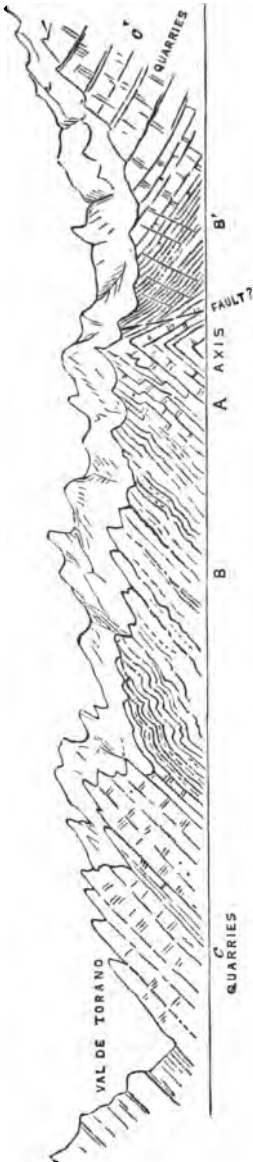
‡ *Bull. Soc. Géol. de France*. Vol. IV., 1069 (1847).

§ *Quart. Jour. Geol. Soc. London*, Vol. V.

¶ Murchison. *Ibid.*, page 267.

of strata amongst the Apuan Alps, and a sketch of the progress of investigations into their structure, I now proceed to describe that portion which came more immediately under my own observation, lying along the valley of the Torano river, which descends from the interior of the mountain and passes outwards into the Gulf of La Spezia by the town of Carrara, under the name of the Carrione.

*Section along the valley about two miles from Carrara.*



C. C'. White crystalline statuary and bluish-veined Marble on opposite sides of anticlinal axis, resting on calcareous mica-schist.

B. B'. Calcareous schist, and mica-schist.

A. Bluish-veined crystalline Limestone; the lowest beds visible in section.

Valley of the Torano.—From the shores of the Gulf of La Spezia, inland to the base of the hills, there extends a plain of varying width, formed of regularly stratified gravel, and with a remarkably level surface richly cultivated. This gravel is unquestionably an ancient shingle beach, or sea-bed, corresponding to the raised beaches which form a fringe along the shores of the coasts of some parts of Britain and Europe. Along this plain the railway from Pisa has been laid, and a branch turns off at Avenza up the valley to Carrara, where it terminates. The cuttings of this branch lay open certain beds of dark shale, limestones and grits, which have been thrown into numerous folds, and are much dislocated. I had no opportunity of examining them, but in all probability they are referrible to the stage of the Lias. Passing through the town, and turning to the left, we find ourselves in a deep ravine, along the bottom of which flows the stream of the Torano, which is utilized for putting in motion the numerous marble-cutting and polishing mills. In front rise the rugged and serrated ridges of white marble, traversed by deep gorges, and their flanks scored by torrents, which in the melting of the winter's snows descend into the valleys with impetuous force. These ridges reach elevations of 4000 or 5000 feet, and culminate in the lofty peak of Altissimo,

which rises at some distance to the north of the Carrara hills. The scenery of this whole district is, indeed, exceedingly beautiful; for the steep and bold ridges of the interior are flanked by ranges of hills of inferior elevation, but clothed to their summits by woods and vineyards, and often crowned by a venerable ruin, or some more modern mansion.\*

A little further up the valley, where it bifurcates, we find ourselves at the base of the steep marble ridge in which a large quarry has been opened, and here my examination commenced. I must now refer to the section intended to illustrate the structure of the rocks in this part of the Apuan range. The valley is on the whole very favourable for making such a section, which was done by pacing and making observations at every change of dip, or composition of the strata. The general direction is from S. S. W. to N. N. E. (Fig. 1, page 53.)

The first bed we meet with consists of light grey and white crystalline limestone, sometimes schistose. It is opened out in a large quarry called "Crestola," and yields ordinary very pale blue, or veined marble, together with statuary blocks, which, I need scarcely remark, are the most valuable of all varieties, and consist of marble in its purest and noblest form. It is only at intervals that a large block free from flaws can be procured. In general the rock is finely crystalline granular, of a bluish tinge, and with occasional bands of schistose rock, passing into calcareous mica schist; it is much fissured by joints, and small crystals of quartz, and iron-pyrites also occur. The thickness of the whole of these beds must be 300 to 400 feet. The dip is here S. W. at a high angle ( $45^{\circ}$  -  $55^{\circ}$ ), and from beneath it emerge a thick series of micaceous schists, passing into calcareous schists, at one place much contorted. The lowest beds, seen at about 350 yards above the quarries, consist of thin-bedded, bluish-veined crystalline limestone. Immediately beyond this there is a sharp folding over of the beds, and the dip is reversed. This anticlinal axis seems to range in a north-westerly direction, and to be accompanied by a fault; for on the eastern side of the axis there is not sufficient room for the entire series of beds which are found on the western side. I, therefore, think there must be a dislocation as well as a fold of the beds. The schists now dip towards the N. E., and are succeeded; first, by greyish-veined crystalline limestone, and ultimately by white crystalline marble, which is largely quarried, and forms the steep ridge at the head of the valley. There can, therefore, be little doubt that this second mass is identical in geological position with the first, which is repeated on opposite sides of the great anticlinal axis already described. These crystalline limestones and schists are continued across the mountain chain, and are flanked on the east, according to Murchison, by low hills of Macigno (Tertiary) sandstone.

*Metamorphism.*—The metamorphic action which has converted the

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\* A view of the approach to the Carrara quarries is given in the Author's work on "Building and Ornamental Stones." (London), 1872.

shales of the Lias into micaceous schists, and the limestones into crystalline marble, has not been accompanied by any extraordinary outburst of igneous rocks. For although such rocks are not altogether absent, they are of very minor importance as compared with the mass of the metamorphosed sedimentary strata. On the other hand, these strata themselves have been subjected to a great amount of disturbance; for in general they are thrown into steep inclinations, or subjected to numerous flexures. It is to such disturbances, under a pressure due to vast overlying masses, since removed by denudation, that we may attribute the development of a high temperature, resulting in the mineralogical change which has supervened amongst these comparatively modern formations. Amongst other results of this metamorphic action has been the total obliteration of organic remains, and the production of serpentinous rocks.

In conclusion, I may only remark that there is nothing singular in the metamorphism of strata so recent as the Jurassic period in this part of Italy, as it has been clearly shown that a large proportion of the crystalline schists and limestones of the Alps of Savoy are referrible to the period of the Lias and Oolite of Britain.

XIV.—ADDITIONAL RESEARCHES ON THE GEOMETRICAL FORMS OF THE SHELLS OF MOLLUSCA. By ALEXANDER MACALISTER, Professor of Zoology, and Comparative Anatomy, T. C. D.

[Read January 10, 1872.]

In a Paper read before the Royal Society of London, and published in the Proceedings for June 16, 1870, I communicated some observations on the mathematical mode of growth of turbinated and discoid shells. The points which I established in that Paper were the following:—1st, that for some species at least there were constant specific parameters which might be of use in the discrimination of species; and secondly, that for discoid shells we required to know one, and for helicoid shells two parameters. Every spiral shell is a geometrical solid, generated by the revolution of the perimeter of a geometrical figure around a central point or axis, and this generating figure, while increasing in size, always remains constant in form. This primary condition of shell-growth was established by the late Rev. Canon Moseley (Phil. Trans. 1838, p. 351), who detected the remarkable fact that the spirals of all gasteropodous shells are true logarithmic spires.

In my former Paper I mentioned that in making measurements there are three points to determine. These are, 1st, the ratio of elongation of radius vector of the spiral. This we will for brevity call  $k$ . 2nd, the degree of linear expansion of the generating figure of the successive whorls  $m$ ; and 3rd, the degree of slipping or translation of the spiral on the central axis. This we will distinguish as  $n$ , or as the helicoidal co-efficient, while  $m$  is the discoidal co-efficient.

In the Paper in the Proceedings of the Royal Society I mentioned that there were only five possible combinations of these co-efficients:—

1.  $n = 0, m = k.$
2.  $n = 0, m < k.$
3.  $n = m, m = k.$
4.  $n > m, m = k.$
5.  $n < m, m = k.$

On the publication of this Paper, the late Canon Moseley very kindly wrote to me, and communicated to me several interesting points and references to works on the subject. As one of the most important of these has not hitherto appeared in any English form, I have ventured to take from it extensive extracts for the purpose of illustrating the subject in hand. I have been deeply indebted to the Rev. Mr. Moseley for his courtesy and frankness in assisting me in my studies. This Paper to which I refer is by Professor Charles Frederick Naumann, of Freiberg, in Poggendorf's *Annals*, Vol. 50, p. 236, and the Rev. Mr. Moseley has also called my attention to the fact that the same geometrical conformation obtains in bivalve as in turbinated shells. The preservation of the geometrical similarity of the shell, as it is enlarged to fill up the opening made when it turns on its hinge, suggests, if it does not make geometrically necessary, the logarithmic form. It may be seen in the section of a bivalve cut at right angles to the axis of the hinge. A bivalve is thus but two turbinated shells of a certain geometrical modulus put together face to face, or rather perhaps a turbinated shell is but one of two separated bivalves developed according to a different geometrical modulus.

Professor Naumann, unaware of Professor Moseley's researches, struck by the great uniformity in the shell of cephalopodous and gasteropodous molluscs, sought to discover how this uniformity could be reduced to mathematical laws. "I therefore determined (he says) first of all to examine by measuring, whether I could discern a law in the successive widths of the whorls. I took for this purpose a specimen of the *Trochus* (*Ziziphinus*) *Conulus*, measured these widths on the same line in the surface across the whorls of the cone." Professor Naumann notes here that in all cases he selected the most uniform specimens, a point to which I have been always careful in attending.

In examining these successive widths to see how they were directly related one to another, "I thence found that the widths of these whorls form a geometrical series, and really a very simple one, whose ratio was  $\frac{4}{3}$  (= 1·3 differing from *Trochus Niloticus*, which is 1·41) I obtained for instance that the widths of four whorls were

Measured.	Estimated at.
28·5 . . . . .	28·50.
21·5 . . . . .	21·37.
16·5 . . . . .	16·03.
12·9 . . . . .	12·02.

A specimen of *Trochus Moniliferus* of Castel Arquato, gave me in like manner a series whose ratio was  $\frac{7}{5}$  (= 1.4 nearer to *T. Niloticus*.) The widths of these and of the other shells measured by Professor Naumann are as follows:—

Name.	Ratio.
<i>Turritella multisulcata</i> , . . . . .	$\frac{4}{3}$
<i>Trochus moniliferus</i> , . . . . .	$\frac{7}{5}$
<i>Turritella terebra</i> , . . . . .	$\frac{7}{6}$
<i>Turritella terebellata</i> , . . . . .	$\frac{7}{6}$
<i>Niso terebellata</i> , . . . . .	$\frac{5}{3}$
<i>Cerithium medium</i> , . . . . .	$\frac{4}{3}$
<i>Terebra fasciata</i> , . . . . .	$\frac{4}{3}$
<i>Buccinum contrarium</i> , . . . . .	$\frac{3}{2}$
<i>Mitra fusiformis</i> , . . . . .	$\frac{4}{3}$
<i>Pleurotoma filosa</i> , . . . . .	$\frac{4}{3}$
<i>Mitra scrobiculata</i> , . . . . .	$\frac{10}{7}$
<i>Turritella vermicularis</i> , . . . . .	$\frac{7}{5}$
<i>Ampullaria patula</i> , . . . . .	$\frac{4}{3}$
<i>Terebra duplicata</i> ,* . . . . .	$\frac{5}{3}$
<i>Pleurotoma cataphracta</i> , . . . . .	$\frac{4}{3}$
<i>Fusus plebeius</i> , . . . . .	$\frac{3}{2}$
<i>Fusus bulbiformis</i> , . . . . .	$\frac{3}{2}$

In *Turritella multisulcata*, the following were the successive whorlwidths, estimated and measured:—

Estimated.	Measured.
0.330, . . . . .	0.330
0.247, . . . . .	0.240
0.185, . . . . .	0.180
0.138, . . . . .	0.135
0.104, . . . . .	0.105

In *Trochus moniliferus*, the following were the widths:—

Estimated.	Measured.
0.330, . . . . .	0.350
0.250, . . . . .	0.260
0.179, . . . . .	0.180
0.128, . . . . .	0.130

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\* This does not agree with my measurement given *P. R. S. loc. cit.* (p. 532), as verified by the measurement of twelve whorls.

In *Turritella terebra* the widths were :—

Estimated.	Measured.
0·360, . . . . .	0·360
0·308, . . . . .	0·310
0·264, . . . . .	0·270
0·226, . . . . .	0·230
0·194, . . . . .	0·190

In *Niso terebellata* :—

Estimated.	Measured.
0·230, . . . . .	0·230
0·191, . . . . .	1·195
0·159, . . . . .	0·160
0·133, . . . . .	0·130
0·111, . . . . .	0·110

In *Turritella terebellata* :—

Estimated.	Measured.
0·930, . . . . .	0·930
0·797, . . . . .	0·800
0·683, . . . . .	0·690
0·585, . . . . .	0·600
0·501, . . . . .	0·510
0·429, . . . . .	0·420

In *Cerithium medium* :—

Estimated.	Measured.
0·430, . . . . .	0·430
0·344, . . . . .	0·350
0·275, . . . . .	0·280
0·220, . . . . .	0·220

“That this law, moreover, governs the inner space or *tortillon* of the animal itself, results from the fact that these same series can be traced in the casts or impressions of the cochleated shells. But this law appears to hold good also in the shells of many Cephalopoda, and above all in Ammonites and those of allied form. Connected with the Ammonites, however, are several circumstances which render an accurate determination of the ratios of their whorls from their widths much more difficult and often quite impossible, as for instance the choking of the chambers with a mass of stone, and in many species the smallness of the spiral. In such cases, therefore, we must find some other means of determining the ratio of the whorls. As the Ammonites are coiled in one plane the mathematical theory of their generation will, so far only as it may be reflected in the law of the whorls, be easier worked out than in the case of the Gasteropoda.”

Professor Naumann sets himself in a second section of his Paper to prove the necessity of this geometrical law of production in the cases of

certain mollusca. In such cases as those like *Trochus Conulus* which have in their volute a rectilineal cone, and make a constant angle with a horizontal plane *einen constanten depressionswinkel*.

"Let the axis of the cone be vertical and  $\beta$  be the angle which the generating line makes with the horizontal plane, at any point at a distance  $b$ , from the vertex of the cone let a horizontal plane be drawn through the axis to which the polar co-ordinates  $r$  and  $v$  are to be referred, the axis of the cone itself being the axis of  $z$ . On these suppositions the equation to the generating line of the cone in any given position will be

$$z + b = r \tan \beta. \quad (1)$$

Since this equation is true for every position in any principal section (hauptschnitte) of the cone, it will by the introduction of the polar angle  $v$  obtain a stereometrical signification, and represent in itself the whole surface of the cone.

Now imagine a point  $P$  in the surface of the cone, from which a curve is spirally generated, always in the same direction, down the surface of the cone and making the constant "descensionswinkel"  $\delta$  with a horizontal plane, an angle which has already appeared on the surface of the cone. The point  $P$  will have the co-ordinates  $v$   $r$  and  $z$  and we obtain the simple geometrical relation

$$\tan \delta = \frac{\sqrt{dr^2 + dz^2}}{r dv}. \quad (2)$$

by equation (1)

$$\begin{aligned} dz &= \tan \beta dr \\ \therefore \tan \delta dv &= \frac{dr}{r} \sqrt{1 + \tan^2 \beta} \end{aligned} \quad (3)$$

and by integrating

$$\begin{aligned} v \tan \delta &= \log r \sqrt{1 + \tan^2 \beta} + c, \\ \text{or } \log r &= v \tan \delta \cos \beta + c. \end{aligned}$$

that value of  $r$  which corresponds to the arc  $v = 0$  we denote by  $a$ , and thus determine the value of  $c$  in the integral to be  $\log a$

$\therefore \log r = v \tan \delta \cos \beta + \log a$  is the equation to the horizontal projection of the required conical spiral.

But this horizontal projection is now manifestly a spiral, and in fact belongs to the class of logarithmic spirals, the *Spira Mirabilis* as Jacob Bernouilli named it on account of its many curious properties. This spiral Professor Naumann calls a concho-spiral, and the indefinite line whose circuit the arc or angle  $v$  determines he calls the *radius vector*, while a definite portion of the above corresponding to the arc  $v$  he distinguishes as the *radius*.

Radii containing equal angles or arcs he calls *equi-distant* radii those enclosing one-fourth he names *quadranto-distant*. Similarly those enclosing  $\frac{1}{2}$  or the whole circumference he names *semisso-distant* and *singulo-distant*. In the hitherto discovered concho-spirals all equi-distant and consequently all singulo-distant radii form a geometrical series which results directly from the equation

$$\log r = v \tan \delta \cos \beta + \log a, \text{ or}$$

$$\log \left( \frac{r}{a} \right) = v \tan \delta \cos \beta. \quad (4)$$

by writing successively  $v + x$ ,  $v + 2x$ ,  $v + 3x$ , &c., for  $v$  and placing  $x = 2\pi$ .

For since the logarithms thus formed of the successive values of  $\left( \frac{r}{a} \right)$  form an arithmetical series, the successive radii must form a geometrical one.

But since the differences in the terms of a geometrical series form a similar series, therefore the successive differences of consecutive singulo-distant radii, that is, the successive widths of the whorls of the concho-spiral exhibit a geometrical series.

Lastly, since the given cone is rectilinear, and its axis passes through the centre of the spiral to whose plane it is perpendicular, the widths of the whorls measured on the helix must therefore evidently form a geometrical series, since the spiral is really nothing but the projection of the concho-spiral on the surface of the cone.

The horizontal projection of the volutes of perfectly conical shells in which the spiral make a constant angle with a horizontal plane is also a concho-spiral, and the widths of the whorls lying on the surface of the cone must of necessity also form a geometrical series.

In all such cases this relation appears to be geometrically necessary, depending on the conditional "verhältnisse" of the animal, how far it is necessary to the existence of the organism that the animal should build its shell exactly conical, and with its whorls making a constant angle with the horizon.

Professor Naumann, in a third section of his Paper, gives another form of the equation for the concho-spiral. "The fundamental law is the same in all logarithmic spirals that the successive equi-distant radii form a geometrical series.

The radius vector revolves round the origin of the curve always in the same direction, and hence many times successively describes the whole periphery round the centre.

A definite radius  $r$  will result from every arc  $v$  described in this manner which will not only be a function of  $v$  but also will be dependent on two constants. One of these which I will call  $a$  is the value which  $r$ , corresponding to  $v = 0$  has at the moment when the radius vector begins to revolve.

The ratio of the series which the singulo-distant radii form shall serve as the second constant. I will denote this by  $q$ , and in future simply call it the ratio of the whorls (windung's-quotient)."

Hence the series of the singulo-distant radii appears to be as follows, starting from the point  $v = 0$  corresponding to

$$\begin{aligned} v &= 0, r = a \\ v &= 2\pi, r = aq \\ v &= 4\pi, r = aq^2. \\ v &= 2n\pi, r = aq^n \end{aligned}$$

and therefore generally for any arc  $v$ ,

$$r = aq^{\frac{v}{2\pi}}. \quad (5)$$

This is for our purpose the most convenient form in which we can give the equation to the concho-spiral.

But this equation really is identical with the one previously deduced from the cone's helix.

$$\log r = v \tan \delta \cos \beta + \log a$$

and gives directly

$$\log r = v \frac{\log q}{2\pi} + \log a. \quad (6)$$

A very simple relation now appears with regard to the Helix in equation 3.

$$\frac{dr}{dv} \frac{1}{r} = \tan \delta \cos \beta.$$

and from the equation

$$r = aq^{\frac{v}{2\pi}}$$

it follows that

$$\frac{1}{r} \frac{dr}{dv} = \frac{\log q}{2\pi} \therefore \log q = 2\pi \tan \delta \cos \beta, \quad (7)$$

and thus both equations are identified, and we have at the same time discovered that the whorl's ratio (windung's-quotient),  $q$  is a function of the two angles  $\delta$  and  $\beta$ .

Since we consider that we have expressed the equation to the concho-spiral by

$$r = aq^{\frac{v}{2\pi}}$$

in the same way we can also inversely obtain the "Schraubenlinie" (helix).

In the centre of the concho-spiral, and in the same plane, let a perpendicular be conceived to be drawn. So soon as we introduce this line as an axis to  $Z$ , and therefore pass from plane geometry to stereo-

metry the equation  $r = aq^{\frac{v}{2\pi}}$  will now gain a stereometric significance and represent the corresponding spiral cylinder, i.e. the cylindrical surface which would be described by a line constantly parallel to the axes of  $Z$  and traversing the concho-spiral.

The question now arises, what properties a curve of double curvature generated in this manner will have? These can be naturally learned from the projection only of the same. This projection is known to us, it is the given concho-spiral. We have now therefore only to seek for a second projection, whilst by means of the angle  $\epsilon$  we introduce the known relation.

However the cylindrical surface on which the line descends may be generated, it ordinarily holds good with regard to this angle that—

$$\tan \epsilon = \frac{dz}{\sqrt{r^2 dv^2 + dr^2}} \quad (8)$$

Since now the equation to the cylindrical surface, viz.,

$$r = aq^{\frac{v}{2\pi}}$$

has in one case been given for the required line, then it will be

$$2dv = \frac{2\pi \cdot dr}{\log q} \quad (9)$$

Substituting this in the expression for  $\tan \epsilon$ .

$$\log q \, dz = \tan \epsilon \, dr \sqrt{4\pi^2 + \log^2 q}$$

and integrating

$$z \log q = r \tan \epsilon \, dr \sqrt{4\pi^2 + \log^2 q} + c. \quad (10)$$

We will suppose the helix to start from the point determined by  $v = 0$  and  $r = a$ , then the corresponding value of  $z$  will likewise be 0, and thus the constant of the integral is determined to be

$$\begin{aligned} & -a \tan \epsilon \sqrt{4\pi^2 + \log^2 q} \\ \therefore z = & \frac{r - a \tan \epsilon \sqrt{4\pi^2 + \log^2 q}}{\log^2 q}. \end{aligned} \quad (11)$$

The generated helix to whose second projection this is the required

equation, lies in the surface of a rectilinear cone whose angle at the base  $\beta$  is determined by the equation  $\tan. \beta = \frac{z}{r-a}$  and then if  $\beta$  be known,  $\tan \epsilon = \frac{\log q \tan \beta}{\sqrt{4\pi^2 + \log^2 q}}$ .

This expression for  $\tan \epsilon^*$  is very convenient for calculating the perpendicular descension's angle of a shell of which  $q$ , or the whorl's ratio, and  $\beta$ , or the angle made by the side of the cone with a horizontal plane, have already been investigated.

Trochus Conulus for example makes  $q = \frac{4}{3}$ ,  $\beta = 61^\circ$ , and  $\log q = 0.2876389$ . Substitute this value and that for  $\tan \beta$  in the preceding formula, and we find that  $\epsilon = 4^\circ 43'$  the perpendicular descending angle of the whorl's suture in the shell.

In Niso terebellata, Fusus plebeius, and Pleurotoma cataphracta, which possess a nearly rectilinear cone, I find that the approximate values of the perpendicular descension's angle in their whorl's suture is

Niso terebellata	$\epsilon = 6^\circ 53'$
Fusus plebeius	$\epsilon = 9^\circ 0'$
Pleurotoma cataphracta	$\epsilon = 10^\circ 22'$

and herein an abbreviation can be permitted so long as  $q$  is not  $> \frac{3}{2}$ . Since  $\epsilon$  is ordinarily a comparatively small angle, and the square of  $\log q$  compared with  $4\pi^2$  also very small (provided  $q < \frac{3}{2}$ ), we can in that case write without at all affecting the accuracy,

$$\tan \epsilon = \frac{\log q \tan \beta}{2\pi}.$$

The angles already determined are, when calculated this way,

Trochus Conulus	$\epsilon = 4^\circ 43'$
Niso Terebellata	$\epsilon = 6^\circ 53\frac{1}{2}'$
Fusus Plebeius	$\epsilon = 9^\circ 1'$
Pleurotoma Cataphracta	$\epsilon = 10^\circ 23'$

values differing from those first found by  $1'$  at the most.

As we before obtained the concho-spiral from the helix, so have we now obtained the helix from the concho-spiral, assuming in each case that the helix made a constant depression's angle with a horizontal plane.

\* The angle denoted by  $\delta$  is the angle made by the suture of the whorls with a horizontal plane, and measured on the cone's surface or tangent plane. The angle here denoted by  $\epsilon$  is the perpendicular descension angle, or the angle made by the whorl's suture with a horizontal plane measured on the surface of the spiral's cylinder, or its tangent plane.

It is really, however, only particular shells concerning which these calculations are true, since it would doubtless be found that the whorl's cone in many molluscs is generated not by a straight but by a curved line, that in others the helix makes not a constant but a variable angle with the horizontal plane. Other spirals also will partly serve as a basis for reasoning on them, although the concho-spiral is reconcilable with a curvilinear cone, whenever a constantly increasing or decreasing descension's angle can be assumed.\*

In his second Paper (Vol. I., p. 236), Professor Naumann applies the study of the concho-spiral to the ammonites, previously noticing some important properties which this logarithmic spiral possesses, resulting directly from the equation,

$$r = aq^{\frac{v}{2\pi}}$$

1st. The concho-spirals have their commencing point not in the centre or origin of the system of axes, but in a fixed point outside the same.

The line evidently begins at that point where  $v = 0$ , but for this value  $r = a$ , which magnitude in future we shall call the parameter of the concho-spiral. If  $C$  is the centre of the spiral, and  $CA = a$ , then the spiral will begin at  $A$  and describe constantly increasing whorls. The parameter  $a$  is an element whose determination can only be performed by means of direct investigation. From this point the spiral extends positively outwards from and negatively inwards towards the centre, to which however it can never reach.

The centre is an asymptotic point to the curve, which therefore separates at this point in opposite directions into centrifugal (positive) and centripetal (negative) portions.

2nd. The successive singulo-distant whorl-widths form a geometrical series with a ratio  $q$ , thus

$$\begin{array}{lll} \text{for } CA \text{ the arc } V = 0 \\ \text{,, } CR \text{ ,, } V = 2\pi \\ \text{,, } CR \text{ ,, } V = 4\pi, \end{array}$$

\* That other spirals will appear is by no means improbable. Many specimens of the Pupa and Clausilia lead us to expect that there are also recoiling spirals.

To represent such a recoiling spiral imagine that  $a$ , any small aliquot part of the semicircle sometimes represents  $10^\circ$ , and that the radii of the spiral to be generated increase according to the following law:—

$$\begin{array}{lll} \text{when } v = 2\pi \text{ then } r = a \sin a, \\ \text{,, } v = 4\pi \text{ ,, } r = a \sin 2a, \\ \text{,, } v = 6\pi \text{ ,, } r = a \sin 3a, \text{ \&c. ;} \end{array}$$

and  $r = a \sin \frac{v}{2\pi a}$  will be the equation to this spiral corresponding to any arc  $v$ . But

this spiral must evidently return to the centre  $v$  when  $\frac{v}{2\pi} a = 180^\circ$ , it again reaches the centre to begin the same motion in the opposite direction.

it follows, therefore,

$$CA : CR : CR' \text{ \&c.} = a : aq : aq', \text{ \&c.}$$

∴ The singulo-distant whorl-widths  $AR, RR', \text{ \&c.}$ , form a geometric series with the same ratio, for these have successively the values  $aq (q - 1) aq^2 (q - 1) q^2$  evidently following in a geometrical series with the ratio  $q$ .

3rd. In every concho-spiral the angle made by the tangent with the radius is constant. This can be easily deduced from the equation of the curve if we make use of the general expression for the subtangent to a curve in polar co-ordinates.

$$\text{sub tan} = \frac{r^2 dv}{dr}. \quad (12)$$

Now by substituting the value of the differential co-efficient (Differential quotient) already obtained for the concho-spiral,

$$\text{sub tan} = \frac{2\pi r}{\log q}. \quad (13)$$

The angle  $w$  made by the radius with the tangent can now be found, since the subtangent meets the radius

$$\therefore \tan w = \frac{2\pi}{\log q}. \quad (14)$$

But  $\pi$  and  $q$  are constant, the angle  $w$  has therefore exactly the same value at any given point, or is a constant magnitude for every point in the same spiral.

4th. Every diameter  $D$  of the spiral consists of the sum of two semisub-distant radii. But one of these is represented by

$$r = aq^{\frac{v}{2\pi}}$$

and the other will therefore be

$$r' = aq^{\frac{v}{2\pi}} \frac{1}{q^{\frac{1}{2}}}$$

and therefore,

$$D = r + r' = aq^{\frac{v}{2\pi}} \left(1 + q^{\frac{1}{2}}\right). \quad (15)$$

For any subsequent larger diameter making an angle  $X$  with the former

$$D' = aq^{\frac{v}{2\pi}} \left(1 + q^{\frac{1}{2}}\right) \cdot q^{\frac{x}{2\pi}}$$

and therefore two diameters  $D$  and  $D'$  containing an angle  $\alpha$  will have this relation

$$\frac{D'}{D} = q^{\frac{\alpha}{2\pi}}. \quad (16)$$

For two quadranto-distal or perpendicularly cutting diameters in the same whorl

$$\frac{D'}{D} = q^{\frac{1}{4}} \text{ or } \left(\frac{D'}{D}\right)^4 = q, \quad (17)$$

and for two coincident semisso-distant diameters, or for the greatest and smallest diameters in the same whorl

$$\frac{D'}{D} = q^{\frac{1}{2}} \text{ or } \left(\frac{D'}{D}\right)^2 = q,$$

and finally for singulo-distant diameters

$$\frac{D'}{D} = q. \quad (18)$$

5th. The widths of two semisso-distant and therefore parallel tangents are proportional to the diameters passing the points of contact. Let tangents be imagined to be drawn through the two extremities of a diameter; then since, as was before shown, the angle contained by the radius and its tangent is always constant, these two tangents therefore must be parallel.

The width  $S$  between the tangents will be generally determined by the equation

$$S = D \sin w$$

where

$$\tan w = \frac{2\pi}{\log q}.$$

For any two diameters  $D$  and  $D'$  will be related to  $S$  and  $S'$ , thus  $D_1' : D' :: S_1' : S'$ , and consequently if these diameters contain the angle  $\alpha$

$$\frac{S}{S'} = q^{\frac{\alpha}{2\pi}},$$

These widths of opposite tangents form a very useful element of investigation in the determination of  $q$ , because they can be easily and accurately measured; they also lead to the determination of the diameter of which the measurement cannot be directly performed, since

$$D = \frac{1}{\sin w} S.$$

6th. The radius likewise cannot be directly measured, since the position of the centre of the spiral is very variable and can only approximately be determined. When a diameter, however, is found, it can then easily be divided into its two radii, because

$$D = r + r' = r(1 + q^4), \quad (19)$$

∴ The smaller radius

$$r = \frac{1}{1 + \sqrt[4]{q}} D, \quad (20)$$

the larger radius

$$r' = \frac{\sqrt[4]{q}}{1 + \sqrt[4]{q}} D, \quad (21)$$

$D$  being a known quantity.

The next section of Professor Naumann's Paper is devoted to the rectification and quadrature of the concho-spiral. Let  $S$  be the length of an arc of the spiral corresponding to any radius  $r$  or of that part of the curve contained by the radii  $a$  and  $r$ . By known rules we determine generally that

$$ds = \sqrt{r^2 (dv)^2 + (dr)^2}, \quad (22)$$

but

$$r = aq^{\frac{v}{2\pi}} \quad \therefore \quad r dv = \frac{2\pi dr}{\log q}. \quad (23)$$

Now substitute this value in the general differential of the arc, and we obtain for the curve of the concho-spiral

$$ds = \frac{dr \sqrt{4\pi^2 + \log^2 q}}{\log q} = dr M. \quad (24)$$

whence by integrating,

$$s = r M + C, \text{ but when } r = a \text{ the arc } s = 0 \therefore$$

$$C = -a M \text{ and } s = r - a M = a \left( q^{\frac{v}{2\pi}} - 1 \right) M.$$

In like manner we can determine for any radius  $r'$  corresponds to the arc  $v + x'$  that  $s' = (r' - a) M$ .

$$= a \left( q^{\frac{v+x}{2\pi}} - 1 \right) M. \quad (25)$$

Let  $x = 2\pi$ , then the length  $U$  of any integral portion of the concho-spiral contained by the arcs  $v$  and  $v + 2\pi$  will be

$$U = s' - s = aq^{\frac{v}{2\pi}} (q - 1) M. \quad (26)$$

Hence we obtain for every concho-spiral

Length of the first revolution,  $a \sqrt{q-1} M$ .

„ second do.,  $= aq \sqrt{q-1} M$ .

„ third do.,  $= aq^2 \sqrt{q-1} M$ .

and

„  $n^{\text{th}}$  do.,  $= aq^{n-1} \sqrt{q-1} M$ .

Let  $f$  represent the collected area which the radius vector has described in its successive revolutions up to the arc  $v$ .

The differential of the area will be

$$df = \frac{1}{2} r^2 dv, \quad (27)$$

or substituting the value of  $dv$

$$df = \frac{\pi r dr}{\log q},$$

but when

$$r = af = 0,$$

$$\therefore f = (r^2 - a^2) \frac{\pi}{2 \log q},$$

and thus for the whole area described by any radius  $r'$

$$f = (r'^2 - a^2) \frac{\pi}{2 \log q}, \quad (28)$$

and therefore the area described by a radius increasing from  $r$  to  $r'$  will be expressed by

$$A = (r'^2 - r^2) \frac{\pi}{2 \log q}, \quad (29)$$

Let now  $r' = rq$ , then we shall obtain the area of a complete revolution extending  $r$  to  $r'$

$$\begin{aligned} A &= r^2 (q^2 - 1) \frac{\pi}{2 \log q} \\ &= a^2 q^{\frac{v}{2}} (q^2 - 1) \frac{\pi}{2 \log q}. \end{aligned} \quad (30)$$

Hence if

$$N = \frac{\pi}{2 \log q},$$

we obtain for any concho-spiral

$$\begin{aligned} \text{Area of first revolution,} &= a^2 (q^2 - 1) N. \\ \text{„ second do.,} &= a^2 q^2 (q^2 - 1) N. \\ \text{„ third do.,} &= a^2 q^4 (q^2 - 1) N. \\ \text{„ } n^{\text{th}} \text{ do.,} &= a^2 q^{2n-1} (q^2 - 1) N. \end{aligned}$$

Therefore the areas of the successive revolutions increase in a geometrical series whose ratio =  $q$ .

In every spiral shell there are many concentric concho-spirals; of these two are especially remarkable—one of which can be distinguished by means of the backs of the whorls, the other by the suture of the whorls—these I will call the inner and outer spiral. They often differ in their values of  $a$  only, while they both possess the same  $q$ . The inner has a smaller parameter than the outer, and both values of  $a$  can be determined by means of the proportion in which the outer revolutions encompass the inner ones. Hence we have two cases in which these two spirals can be reduced to one.

1. When the revolutions enclose each other to the centre.
2. When they do not enclose each other, but only touch.

Many ammonites, however, are characterised by different whorl ratios  $q$  and  $k$  in the outer and inner spirals.

We can therefore divide the ammonites into mono-spiral and diplo-spiral, and the last again into exosthene, as *A. Reinecci*, *tumidus*, and *entosthene*, as *A. flexicostatus*, *Brodicei*, *costatus*, according as the outer or inner whorls have the larger ratio.

In any case the outer and inner spirals differ from each other by a relation which is of the greatest importance, namely, that the inner spiral is, with regard to the outer one, a whole revolution behind—that the suture also of each revolution is not of the same form as the ridges of that revolution; but of those of the one immediately preceding it; hence it follows that corresponding to the former, a mere inner revolution of the outer spiral, there is no inner spiral, and that this latter commences when the former has already completed at least one, and is beginning a second revolution. This relation might possibly be verified by the difference between the embryo and the self-dependent animal. The embryo is perhaps provided with the first whorl only, in which the condition for the development of the whole shell must necessarily be produced; but if the animal, now become self-dependent, grow, then the second whorl will gradually be formed, and at the same time the formation of the suture will also begin, which in mono-spiral shells is presumed to be a spiral of less parameter. The smaller the parameter  $ca$  of the suture-spiral is, as compared with that of the ridge-spiral, so much the more will the whorls of the shell encompass one another. When  $ca = 0$  there is no suture, or the whorls completely enclose one another even to the centre, and the inner spiral vanishes; on the other hand, the larger  $Ca$  is not so much the less, and the revolutions of the shell encompass one another. When  $Ca = CA$  the revolutions are only adjacent and the inner spiral equals the outer, it must nevertheless be at least a whole whorl behind, as it is just in this case that the necessity for the inner spiral thus being a whorl in the rear appears to be most obvious. If it can be assumed that in mono-spiral ammonites the suture-spiral is exactly a whole whorl behind the ridge-spiral, and if we denote the radius of

the ridge by  $r$ , that of the suture by  $\rho$  for any position on the same revolution, then  $r = aq\frac{v}{2\pi}$  and  $\rho = aq\frac{v-2\pi}{2\pi}$ . If the diplo-spiral ammonites have in both spirals equal parameters the ridge-spiral in the entosthenic species must be about two revolutions before the suture-spiral.

The whorl ratios are the most important elements in the Morphology of spiral mollusca generally but particularly of ammonites. There are two methods in particular which we can make use of in determining the ratios of whorls in ammonites according as the examples at our disposal are transversely divided or entire.

Measurements made on transversely divided ammonites allow of the greatest certainty and exactness in the determination of the whorl's ratio. Many divided and polished specimens may be found in our museums, in which the surface of the section is about parallel to the plane of the whorl; such sections may be very valuable in the determination of  $a$ , but in determining the whorl's ratio they have no particular value, because the section must be exactly central and perpendicular to the axis to be of any use, and even then the law of the outer spiral alone can be discovered.

On the other hand those sections rarely found in our museums which are perpendicular to the plane of the whorl, and as nearly as possible central, assist us greatly in our present investigations. Although they can never be more than nearly central, still they allow of our discovering the whole anatomy of the specimen in its true uniformity, as well with regard to the ridge as the suture-spiral, and the possessors of good collections will render a service to this branch of science by procuring a similar anatomical preparation of the most perfect and best developed specimens of every possible species and then measuring them. It will be seen from such a transverse section of an ammonite that if  $rr$ ,  $r'r'$ ,  $r''r''$ , &c., be singulo-distant diameters of the outer spiral and  $\rho\rho$ ,  $\rho'\rho'$ ,  $\rho''\rho''$ , &c., singulo-distant diameters of the inner spiral, then it is necessary only to measure two or three such diameters to determine the ratio  $q$ , for

$$\frac{rr}{r'r'} = \frac{r'r'}{r''r''} = q,$$

and in like manner

$$\frac{\rho\rho}{\rho'\rho'} = \frac{\rho'\rho'}{\rho''\rho''} = K.$$

If we find that  $\frac{rr}{r'r'} = \frac{\rho\rho}{\rho'\rho'}$ , then the species under consideration belongs to mono-spiral ammonites. On the same section the height

of the revolution, and the proportion of the enclosure or boundary can be measured with greater exactness. The small measurements which I could make in some species convinced me that very exact results may be obtained in this manner, and that only the last whorl (filled with a mass of stone) in which the animal at the last resided, and the inner spiral not yet completely developed, appears to be not always formed with sufficient uniformity or to be disfigured by pressure. This part of the shell then is also less adapted for measurements; moreover these and similar measurements, especially those made in the smaller species, will lead to accurate results only when they are obtained by the aid of a particular instrument, which consists simply of a brass rule with divisions resting on a frame and supporting a nonius, which is again fastened to a microscope containing cross threads. The microscope and nonius will be capable of being moved backwards and forwards on the rule by means of a screw.

Professor Naumann in the succeeding paragraph considers the determination of the ratio  $q$  or  $k$  from the distance of opposite tangents, "The distances of two semisso-distant tangents are proportional to the diameters corresponding to these tangents. If therefore the distance of one pair of tangents =  $S$ , and if the other pair =  $S'$  and the diameters corresponding to these pair of tangents form an angle  $\alpha$ , then

$$\frac{S'}{S} = \frac{D'}{D} = q^{\frac{\alpha}{2\pi}}$$

Hence we determine

$$q = \left( \frac{S'}{S} \right)^{\frac{2\pi}{\alpha}}$$

$$q = \left( \frac{S'}{S} \right)^2$$

$$q = \frac{S'}{S}$$

according as the diameters corresponding to the given pairs of tangents are quadranto-distant, semisso-distant, or singulo-distant.

"The method of the determination of the ratio  $k$  from the widths of the whorl-suture is only available for the inner spiral, since the whorl widths in the outer spiral cannot be ascertained. It depends on the relation that the singulo-distant widths of the whorl's suture form a geometrical series with the same ratio  $k$  as the singulo-distant radii, and if the suture is not covered with a mass of stone, but can be traced in several revolutions and is stamped distinctly out, then it will be necessary to measure only two or three successive widths within this radius-vector, in order to determine the value of the whorl's ratio."

## XV.—REPORT OF COUNCIL.

At the termination of another year of office, your Council have the gratification of reporting the continued prosperity of the Society, both in the numbers of the ranks of its Fellowship and in its financial condition. Our eight meetings have been well attended, and the Papers brought forward at them have been of an interesting and valuable character.

We have lost by the hand of death, some of our most valued members, among whom, in the foremost rank, we must mention the name of our respected Honorary Member, Sir Roderick Murchison, whose loss we deeply deplore, in common with all our sister Geological Societies, and though this is not the place to record his labours and his well-merited honours, yet we cannot permit his name to be erased from our list without dropping this our tribute stone of regret on his memorial cairn. The death of Robert Callwell, so long a Fellow-Councillor and Vice-President of this Society, is also a deep personal loss which we all cannot but feel, for although he did not contribute much to the scientific work of the Society, yet his clear judgment and conscientious business habits and wise counsel have often been of incalculable advantage to the well-being of the Society. In Mr. George Dixon also we have lost a judicious Councillor, and a genial, hearty lover of our and kindred sciences.

During the past year ten new Fellows have been elected to fill the five vacancies made by death.

The following is a list of the Papers which have been read at our Meetings. In March at the Joint Meeting of the Geological and Zoological Societies:—E. Hardman, "On the Occurrence of Gypsum in the Keuper Marls of Croagh, Co. Tyrone."

At the April Meeting.—1. W. H. S. Westropp, "Sketch of the Physical Geology of North-West Clare."

2. E. Hull, F. R. S., "Remarks on the Report of the Royal Commission on the Coal Resources of Great Britain and Ireland."

3. G. H. Kinahan, "On the Discovery of Tertiary Iron ore and Lignite in the Basalt of Co. Londonderry."

At the May Meeting.—J. E. Reynolds, "Notes on Woodwardite."

At the June Joint Meeting of the Geological and Zoological Societies:—E. Hull, F. R. S., "Further Observations on the Well at St. Helens, Lancashire."

XVI.—ON A REMARKABLE FAULT IN THE NEW RED SANDSTONE OF RAINHILL, LANCASHIRE. By EDWARD HULL, F.R.S., F.G.S., Director of the Geological Survey of Ireland.

[Read February 14, 1872.]

SOME months since I was consulted by the Corporation of St. Helen's, Lancashire, regarding the best site for a deep well from which to augment the present supply of water for the use of the inhabitants of the borough.

The first place I selected was in the vicinity of Halsnead Park, about ten miles S. of St. Helens, but as the site was objected to by the proprietor, we were obliged to have recourse to another position; and the place ultimately fixed on was a field near Cumberlane House, Whiston, close to the Liverpool and Manchester Railway;\* a position, however, from which I did not anticipate so large a supply as from Halsnead.

The reasons for the selection of this site were chiefly these:—The rock is the upper member of the Bunter Sandstone (New Red Sandstone or Trias), which is the chief water-bearing rock of this part of England. The dip of the bed is westward, and at 200 yards to the west of the site the New Red Sandstone is abruptly terminated by a large fault which ranges in a N. and S. direction, and on the other side of which we have Upper Carboniferous strata.

At some distance to the east of the well, the beds of New Red Sandstone rise into a hill, called Rainhill Hill, about 260 feet in elevation, and nearly 100 feet higher than the site of the well; and as the strata are everywhere exposed at the surface, and consist of moderately soft-porous sandstones and conglomerates, I looked upon this hill and the bordering tract to the north and south as so much gathering ground for water supply; moreover, as the position of the well was in the direction of the dip of these beds, it was inferred that the water would percolate in this direction, and be banked up against the side of the fault already described. The section in the following page will illustrate the position of the strata.

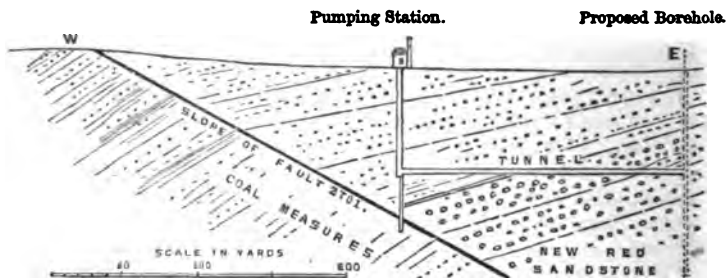
As the fault was seen to reach the surface at a distance from the proposed site of the well of 200 yards, I anticipated that before crossing it in the well or borehole, a depth of at least this amount, and probably considerably over this, would have to be reached before the fault would be met with; as the usual inclination of the faults of this part of the country, as ascertained by actual mining, has been found to be 2 vertical to 1 horizontal; and I estimated that after having sunk a

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\* See six-inch Map of the Geological Survey. Lancashire Sheet 107.

well, and made a boring from the bottom of it to a depth of about 150 yards, a supply of good water to the extent of 700,000 or 800,000 gallons might be obtained.

*Section through the new Pumping Station of the Borough of St. Helens, Lancashire.*



These anticipations were, however, not fully realized owing to an unlooked for source of error. The well was sunk successfully to a depth of seventy-five yards, and a borehole put down to a depth of thirty-five yards further, making the total distance from the surface 110 yards. It was found, however, that the rock had changed its character, for at a depth of 104 yards from the surface, a fine-grained, compact, slightly micaceous purple sandstone was reached, which yielded no water, and suggested to the resident engineer a suspension of operations.

On seeing the specimens brought up from the borehole, I at once recognised them to belong to the Upper Coal-measures; and recommended that the boring should be discontinued.

It was therefore clear that the fault had been passed through at a depth of 104 yards, and at a point where a bed of sandy clay and broken rock had been met with; and that the slope, or hade of the fault was actually 2 horizontal to 1 vertical, a slope so gradual, that if not unprecedented, is at least of extremely rare occurrence.\*

The quantity of water obtained at the depth of the borehole was only about 400,000 gallons per day; or less than half the required supply. If the slope of the fault had been steeper, and a greater depth of sandstone been available, the quantity would have been largely

\* I only know of one other such instance in Lancashire, viz.:—the slope of the Great Haig Fault, N. Wigan. In South Staffordshire, this is a fault at Wyrley, forming part of the boundary of the Dudley Coal-field, having a slope of 2 horizontal to 1 vertical. See Mr. Jukes' section, sheet 23, Geol. Survey.

increased, as one half the amount of water was obtained from that portion of the well between 52 and 59 yards from the surface. It had also been intended to tunnel in two directions into the sandstone in order to intercept the flow of water from joints and fissures. Under these circumstances, in order to increase the supply, and to make use of the machinery erected for pumping at the station, I have advised the Corporation of St. Helens, to sink a bore-hole at a spot 200 yards still further to the east of the present site, and to connect it by a tunnel with the bottom of the existing well. Supposing the slope of the fault to continue, as ascertained at the well, we shall have a depth of 208 yards of New Red Sandstone to penetrate if necessary; and we have reason to expect a very large increase of water, not falling much below the original estimate.

XVII.—SKETCH OF THE PHYSICAL GEOLOGY OF NORTH CLARE. By  
W H. STACKPOOLE WESTROPP, M. R. I. A.

[Read 10th April, 1872.]

As the Geology of Clare was thoroughly well described by the late lamented Mr. F. J. Foot, in the Explanations of the Maps of the Geological Survey of Ireland, I do not think it necessary to do more than call the attention of the Society to some of the principal peculiarities of a very peculiar district.

The rock-formations of North Clare are the Upper Carboniferous Limestone and Coal-measures.

No two countries could present a greater contrast in physical features than the Limestone and Coal-measure districts. If we were to designate them from the general look of the rocks, one might be called the gray country, the other the black country; if from the vegetation, one would be the green, the other the brown country; if from the superficial features, one the rocky, the other the moorland country.

Limestone occurs principally in the Barony of Burren, Coal-measures in the Barony of Corcomroe. Strange to say, the fine ruined abbey of porcomroe is in Burren, and is twelve miles distant from the nearest point in the Barony to which it is sponsor.

*The Limestone Country.*

In common with Galway and Middle and South Clare, Burren has but very scanty superficial deposits. Unlike Galway and the rest of Clare, where the Limestone forms the plains, in North Clare it rises into mountainous masses, forming a great series of rounded hills, intersected

by deep and often steep valleys, and having an average height of nearly 1000 feet.\*

From the sea-level to the summits, these hills are composed of bare gray Limestone, which, owing to its having no superficial soil, and the inclemency of the weather, has been furrowed and eroded in the most extraordinary manner. The joints in the rocks, running in straight lines for hundreds of yards, and crossing at various angles,† have been so opened up, that a man could go down bodily into some of them and disappear from the face of the earth.

Strangers are much astonished when they learn that land which at first sight appears to produce nothing but a crop of stones generally fetches a good rent; but the fact is, the richest of herbage grows in the clefts and furrows between the rocks, and is highly prized for fattening stock; there is no sweeter mutton in the kingdom, than that fed in Burren. This is also a famous botanical region; the late Mr. Jukes called it a natural conservatory. In the deeply eroded crevices a vast number of rare and delicate plants flourish, and successfully resist the rough winter storms of the Atlantic. The humidity of the air and the pervious nature of the ground are particularly favourable to the growth of ferns.‡

The most conspicuous feature in the Limestone hills is the way in which they are terraced. The sides appear from a distance, even from the coast of Galway twelve miles off, like huge steps of stairs. Strangers have often asked me if these terraces are not raised beaches. A few persons, more learned in the mysteries of nature, suggest that they are similar to that geological crux—the parallel roads of Glen Roy. As nobody knows anything about the parallel roads, or rather, as each distinguished investigator holds a different view from everybody else, I cannot take it upon myself to say if *they* are similar to our Burren terraces, but certainly the latter are not raised beaches. In every case they coincide with the bedding of the rock. On the northern shore from Black Head eastward, and forming the southern side of Galway Bay, the strike of the beds coincides with the outcrop. Here the terraces are horizontal, and can be traced for miles winding around the hills and along the sides of the valleys. Viewed from the west, they dip gently to the south. Wherever the beds form undulations, the terraces do the same. North of Corrofin is a hill in which the beds form an anticlinal—the terraces do likewise. West of Gort there is a very conspicuous hill in which the beds are synclinal—so are the terraces. I may

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\* The highest hill in Burren, Sliab Carran, has an elevation of 1075 feet; Black Head, so conspicuous from the opposite Galway Coast, is 1041 feet high.

† These joints have been well described, figured, and compass-bearings given, by Mr. Foot in the Explanation to Map 114 Geol. Survey Ireland.

‡ See Transactions of the Royal Irish Academy, Vol. xxiv., Science, "On the distribution of Plants in Burren." By F. J. Foot, M. A.

here remark that the strata in this part of Ireland have been very little disturbed. In Burren the beds have a gentle dip to the south-west, rarely reaching to  $5^{\circ}$ ; there is, hardly an undulation, and I have not detected a fault of even one inch in the whole district. However, at no very great distance from the locality under consideration, there are abundant flexures in the rocks. I cannot help looking at the terraces as anything but the result of atmospheric erosion along the planes of bedding. In a few places where they are particularly well marked, I have detected siliceous layers in the limestone.

A curious feature in Burren is the occurrence of excavations or depressions in the rock surface. They have vertical sides, and are so deep and extensive that one or more good-sized houses could fit in some of them. They vary in the number of sides, some having only three, but many more having four sides. The sides are always continuous with the joints in the adjacent surface. This suggested the clue as to their formation to Mr. Foot, who thought that they were depressions or subsidences of rock masses, bounded by intersecting open joints, and where the limestone beneath was dissolved away by water containing carbonic acid gas in solution. On the side of a high hill north-east of Ballyvaughan, there is a chasm with vertical sides, which Mr. Foot thought was similarly formed.

As in most limestone districts there are numerous caves. Those at Sliab Elva and at Kilcorney are very extensive; they have never been thoroughly explored. Some foolhardy individuals attempted to explore them, after having fortified their nerves with liberal allowances of whiskey; under the influence of the potent spirit they beheld, while in the caves, divers strange sights and visions, the description of which has quite deterred the natives from following their example.

There is a great apparent scarcity of water, and this is the more remarkable since the climate is rather damp. Water is really abundant, but unfortunately it is beneath the surface. Nearly all the rivers run underground. Rivers rising in the coal-measures plunge underground the moment they touch the limestone. Sometimes it is impossible to trace the courses of the rivers; but generally they can be made out, as there are deep holes in the surface communicating with them. After heavy rains the subterranean channels appear to be insufficient to carry off all the water, and the excess rises up through the holes to the surface and floods the surrounding lands.

#### *The Coal-Measure Country.*

There are not nearly so many features of interest in the coal-measure country as in the limestone. The rocks immediately overlying the limestone are black, friable, bituminous-looking shales, in some places full of fossils. Over these come alternations of grits, flags, shales, with occasional calcareous bands. There is no coal worth working; a few thin beds of very bad quality have been detected. The general

look of the country is that of a brown undulating upland, with plenty of moor. The scenery is not very attractive, though to those who like an undulating open country free from trees, it has a charm of its own. The coast scenery, however, is of unsurpassed magnificence. Except where there is some quantity of limestone drift, the herbage has a poor burnt look, contrasting strongly with the beautiful verdure of the scanty vegetation on the limestone, which retains its greenness even in the depths of winter. Very different from the large hill masses of the limestone, the coal-measure country is composed of multitudes of small hills. I cannot compare them to anything but the billows of the ocean. These are very abrupt when situated in the larger main valleys, as at Ennistymon. In the open upland country they form smoother undulations.

The escarpment of the coal-measures is very well marked everywhere, though nowhere so well as at Lisdoonvarna. This place has of late years become rather celebrated for its mineral waters, and is much resorted to by invalids. The spas are chalybeate and sulphuretted hydrogen. Chalybeate waters are very abundant throughout the coal-measures; indeed, it is difficult to get water free from iron. One spa, called "The Twins," is somewhat of a curiosity; only two inches apart are two small wells, one is a pure chalybeate, the other a pure sulphur spa. Lisdoonvarna is situated immediately on the junction of the coal-measures and limestone. The chief peculiarity of the locality is the number of deep ravines which abound in the neighbourhood. They are cut down through the soft coal-measure shales to the limestone, and it is possible to walk for miles along the bottom with limestone beneath and shales on either side. Owing to the propensity which water has for plunging under ground when it touches the limestone, many of these ravines have no water in them except after very heavy rains. The mode of formation of some of them puzzled me a good deal for some time. I beg to suggest an explanation upon which I should like to have the opinion of experienced geologists. I must guard myself, however, by saying that the following explanation is only applicable to a few particular cases, and does not refer to the larger ravines running east and west along the main valleys, but only to some of the narrower and steeper ones running north and south, which appear to be cut across hills. I think they were probably formed by the falling in of the roofs of subterranean rivers. The rivers run for considerable distances underground on the limestone. The sides of the ravines, often from fifty to one hundred feet high, are steep cliffs of black shale. On walking up the bed of a nameless dry watercourse which runs through the townland of Knockaskeheen, in the steepest part of the glen, one arrives at a place where there is a complete barrier of undisturbed shale, extending across the ravine; a little further on, above this, the glen becomes as deep, and the sides as steep, as before. I cannot conceive how this barrier could be left *in situ* if the valley were formed by gradual erosion from above down-

wards. Again, on walking up the Rathbaun ravine, one comes to a place where the stream forsakes its old course, leaving the valley dry, and may be seen issuing forth freely through the limestone forming the substratum of a coal-measure hill over one hundred feet high. Less than a quarter of a mile farther up the valley, the river may be seen plunging beneath the hill. Where the water comes out, the roof of the channel has fallen in for about fifty yards, and I think it will be only a matter of time for it to fall in along the whole course of the stream.

### *Surface Geology.*

I have observed polished and striated rocks in the following places:—

In the limestone country at Finnevara (first noticed by Professor King of Galway).	} Striæ about N. to E
Ballyalleban (two miles south of Ballyvaughan).	
Foot of Corkscrew Hill.	
Poulsallagh (on seashore north of Roadford).	

Near Kilfenora and Corrofin there is polished limestone, but no striæ were found.

In the coal-measures I noticed striæ with an E. and W. direction, near highest point of the Cliffs of Moher.

The many small hills described above as characteristic of the coal-measures—in this part of the country, at least—are composed of boulder drift, and are similar to those in other parts of Ireland, to which the name “drumlins” has been applied. Mr. Close has observed that the long axis of drumlins coincides with the direction of striæ in other parts of Ireland. In the country under consideration, neither the grits nor shales are favourable for the preservation of striations, so that the direction of the drumlins becomes of some importance. This is nearly always about E. and W., and coincides with the only striæ (near Moher) which I have yet noticed. It would be beyond the scope of this paper to enter with greater minuteness into this subject; but I hope to be able to direct special attention to it in another paper.

In the limestone country there are thick deposits of true boulder-clay in many of the valleys. It contains an abundance of polished and scratched local rock, the blocks being sometimes very large. In some places it is very peculiar. The binding material—if there ever was such—has been removed, and the blocks of stone are piled one on the other, forming masses which look like huge cars, and might be almost dignified with the name of hills.

Rounded boulders of granite, such as occurs *in situ* on the opposite coast of Galway, twelve miles distant, are very abundant in the north. They always lie on the surface, and form no part of the boulder-clay, which is a purely local deposit. They are very numerous in the neighbourhood of Ballyvaughan, and the walls of some roads being built entirely of granite! They become very scarce further south, and in the coal-measures occur only very few and far between.

**XVIII.—OBSERVATIONS ON THE RESULTS DETERMINED BY THE ROYAL COMMISSIONERS APPOINTED TO INQUIRE INTO THE COAL-RESOURCES OF GREAT BRITAIN AND IRELAND. By PROFESSOR EDWARD HULL, M.A., F.R.S., Director of the Geological Survey of Ireland.**

[Read April 10, 1872.]

THE author commenced by remarking upon the great importance to the social well-being and commercial supremacy of Great Britain of the possession of supplies of coal; this mineral being the almost exclusive source of motive power at present in use, and upon which we are daily becoming more dependent for the purposes of locomotion by land and sea, the motive power for machinery, and as a source of heat for the smelting and manipulation of iron and other metals.

As it was known that the consumption of coal was increasing rapidly, and that the mineral itself was not capable of being reproduced, the British public sometime since began to anxiously inquire—for how long a period this drain on our coal-fields was capable of being maintained. Sir Robert Peel had consulted the late Dr. Buckland on the subject; and during the debates in Parliament in 1859, when the commercial Treaty with France was under discussion, the opinions broached by different Members were of so contradictory a nature, that the Government readily acceded to the motion of Mr. H. Vivian, M. P., and appointed a Royal Commission of unpaid Members to inquire into this and cognate matters. The appointment is dated 28 June, 1866; and the Commission was placed under the Presidency of the Duke of Argyll, with whom were associated Sir R. J. Murchison, Sir W. Armstrong, Professor Ramsay, Professor Jukes, and several other gentlemen of eminence.

During the discussion on "the Coal-question" in Parliament, seven years previously, the author felt desirous of finding an answer—as far as it was possible for a single individual to do so—to the oft repeated question "how long can our Coal-resources last?" and with this object made a series of estimates of the quantity of coal in all the important British coal-fields, the results of which were published in 1860.\* Taking the limit of depth at 4000 feet, he found there was sufficient coal to last for one thousand years, at the rate of consumption for 1860. In that year the quantity of coal raised was 79,923,273 tons, and the quantity of coal estimated by the author was 79,843 million of tons. The output of coal has, however, risen to 110½ millions of tons in 1870,† and is yearly increasing at a variable rate, averaging a little over three millions of tons per annum between 1855 and 1869; and the problem stands thus:—given a certain quantity of coal, and the rate of consump-

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\* "Coal-fields of Great Britain" (3rd Ed., 1873.)

† Mineral Statistics of Great Britain and Ireland for 1870. By R. Hunt, F. R. S.

tion being variable, how long will the coal last? and one of the questions to which the Commissioners directed their inquiries was to ascertain the probable rate of increase of consumption in the future.

Upon this question the Commissioners do not hazard a definite report, but with certain data before them discuss the views of Mr. Jevons, who, in his work on "The Coal-question," in 1865 argued that the rate of increase of about  $3\frac{1}{2}$  millions of tons would continue for a very lengthened period, so that the coal supply would be exhausted in about 110 years. He calculated that in 1861 the quantity raised would amount to 118 millions of tons; but from the average rate of increase, we now know that it will fall short of this by about four millions of tons, so that there appears to be an element of error involved in Mr. Jevons' calculations.

On the other hand, Mr. Price Williams has suggested that the annual rate of increase is likely to proceed on the basis of a diminishing ratio, depending on the rate of increase of population. Thus it is found that the increase under this head, between 1811 and 1821, was at the rate of 16 per cent., while in the last decade it was only 11.75 per cent. These two rates of increase, in conjunction with those of the intervening decades, form the elements of a curve, which may be carried forward so as to show the extent of population in future years. Mr. Price Williams considers that the present rate of increase of consumption of 3 per cent. is not likely to continue, but has in fact passed its maximum and will decrease in future years, and that the now estimated quantity of coal available for future use would, upon this view, represent a consumption of 360 years. (Report, Vol. I., p. 16.) I shall again revert to this question.

Coming now to the results arrived at by the Commissioners as regards the quantity of coal available for supply, they report that there exists (1), in the visible coal-fields within a depth of 4000 feet, 97,528,126,210 tons of coal. (2.) In the concealed coal-fields beneath Permian and Secondary formations 56,273,000,000 tons, to a depth of 4000 feet; and at depths beyond this, 48,465 millions of tons, of which "it is entirely a matter of conjecture whether any or what portion can ever be worked," the great obstacle being the supposed high temperature at these great depths.

As regards the limits of deep mining, the Commissioners find that the only serious impediment is the increase of temperature. From the evidence laid before them, they conclude that at 3000 feet the strata would probably have a temperature of blood heat, the general rate of increase being  $1^{\circ}$  Fahr. for every 60 feet. By means of ventilation, however, they consider it probable that it will be possible for mining operations to be carried on to a depth of nearly 4000 feet; and they have, therefore, adopted this limit, which the author may remark was the same as assumed by himself on similar grounds.

On the subject of waste in working or mining the coal itself, the Commissioners find, notwithstanding a general improvement in the

method of working coal, especially under the "long wall" system, that there is still frequently a culpable waste of coal permitted in many districts, resulting in loss to the community at large. With regard to waste in combustion, the Commissioners state that unquestionably coal is wasted by carelessness and neglect in large quantities; nevertheless, that for some time past, in our manufactures, there have been constant and persevering efforts to economise coal, and that in some branches of manufacture the limits of a beneficial economy appear to have been nearly reached. Thus in the smelting of iron ore, about 30 years ago, while no less than 5 tons of coal were required for one ton of pig-iron, the quantity has now been reduced to less than 3 tons; and at Middlesborough, in the Cleveland district, to about 23 cwt. of coke per ton of pig-iron.

The question of the extension of the coal-fields beneath the newer formations of England has been ably handled by Professor Ramsay and Mr. Prestwich—the former taking the central and northern districts, the latter the south of England: on these subjects the reader must be referred to the Report itself.

*Ireland.* The author concluded:—It will be expected that in this assembly I should make some special reference to the resources of the coal-fields of Ireland. The late Professor Jukes, having been nominated one of the Commissioners for investigating the coal-resources of this country, took some preliminary steps in order to fulfil the trust committed to him. After his lamented decease, the inquiry was entrusted to myself, and with the assistance of two of my colleagues of the Geological Survey, Messrs. Kinahan and O'Kelly, I was enabled to present what may be regarded as an approximately correct return of the available coal in the several coal-fields as follows:—

	Available tons of coal.
Ballycastle (Co. Antrim) coal-field, .	16,000,000.
Tyrone, . . . . .	6,300,000.
do. under newer formations, .	27,000,000.
Leinster (Queen's Co., Kilkenny), .	77,580,000.
Tipperary, . . . . .	25,000,000.
Munster (Clare, Limerick, Cork), .	20,000,000.
Connaught (Arigna District), .	10,800,000.

Total, . 182,680,000 tons.

It will be satisfactory to the Members of this Society to learn that so large a quantity of coal remains for use in this country, the most important districts being those of Leinster and Tyrone, in the latter of which large deposits of bituminous coal lie concealed under Triassic strata.

And here I may be allowed to refer to the able Reports drawn up by that veteran Geologist, the Vice-President of this Society, Sir Richard Griffith. These Reports, presented to the Royal Dublin

Society some years ago, give a true account of the resources of the coal-districts to which they refer. And when I find it recorded by this author in 1829, that there are no less than thirty feet in total vertical thickness of coal in Tyrone (when all the seams are added together), it seems incredible that these deposits of mineral fuel should not have been turned to use by the spirited manufacturers of the North of Ireland to this day; and that (as I myself have seen) coal is actually imported from England and Scotland into Coalisland to turn the machinery of the factories in that neighbourhood.

There are evidences, however, that the manufacturers and others interested are about to turn their eyes to the resources of mineral fuel lying at their own doors; and that when the Government Geological Survey now in progress in that district shall have been completed, the public will become informed of the true state of the case, and no longer permit these beds of coal to lie undisturbed near the western shores of Lough Neagh.

In conclusion, it must be evident that no one can venture a conjecture as to the duration of our coal-supplies. The production can never reach a maximum and then suddenly collapse. As the depth increases in consequence of the exhaustion of the shallower seams of coal, the expense of mining will also increase, and the cost of coal to the consumer. And when other countries, such as America, shall be able, in consequence of the high price of coal, to compete, and outbid us, in the markets of the world, and in manufacturing enterprise, then the commercial greatness of Britain will be on the wane, and her place amongst the nations will depend on those ennobling social and national virtues without which no country can remain great and prosperous.

**XIX.—TERTIARY IRON ORE IN THE CO. LONDONDERRY. By G. H. KINAHAN, M. R. I. A.**

[Read April 10, 1872.]

THE writer of this notice stated he had recently found a bed of Limonite in the hills called Bohil breaga, townland of Moydamlaght, Co Londonderry, on the property of the Drapers' Company, whose estates he was examining for coal and minerals. The iron ore is known to occur in considerable quantities in conjunction with the exotic rocks of Tertiary age at the eastern limits of the great plateau of Doleryte that occupies so large a portion of north-east Ireland, but previously it had not been recorded on the west of that tract. He also pointed out that a little further east in the townland of Dunmarry, the limonite was replaced by a bed of lignyte from 10 to 20 inches high.

The section at Finiskey, in Moydamlaght, was as follows:—

Massive whinstone (doleryte), . . . . .	over 100 feet.
Rotten whinstone stealtitic amygdaloid, . . .	about 15 „
Limonite, . . . . .	3 „
Indurated chalk and flint gravel, . . . . .	3 „
Red fire (Bunter?), . . . . .	over 100 „

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The author, in conclusion, drew attention to the thinning out of the chalk towards the north-west as on the east of the plateau of Doleryte. The cretaceous beds are about 200 feet thick, while to the west in the neighbourhood of Moneymore they never reach 50 feet. At Slieve Gallion-carn (north-west of Moneymore) there is barely 20 feet of them, while farther north-west in the Ballynascreen hills (Bohilbreaga), they cannot be more than from three to six feet in thickness.

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XX.—NOTES ON WOODWARDITE.—By J. EMERSON REYNOLDS, M.R.C.P.,  
Professor of Analytical Chemistry and Keeper of the Minerals,  
Royal Dublin Society.

[Read May 8, 1872.]

IN 1866 Professor Church, of Cirencester College, described a mineral to which he gave the name of "Woodwardite." According to the first published analysis, this mineral may be regarded as a highly basic hydrated copper and aluminum sulphate, if its title to stand as a distinct species be admitted. The specimens were obtained by Church from Mr. Talling's Cornish collection, and are described as being of a rich turquoise-blue, or slightly greenish blue colour—destitute of distinct crystalline structure, and as forming a curiously "rippled" deposit on rocky surfaces.\*

During several visits to London I have collected amongst the mineral dealers a number of specimens of minerals differing considerably in appearance from each other, and all labelled "Woodwardite." These specimens afforded widely different results when submitted to chemical analysis, and with a single exception did not correspond either in properties or composition with Church's Woodwardite. Some of these specimens I have laid on the table for your inspection.

While some of the analyses were in progress last summer, Professor

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\* Journal of Chemical Society, Vol. IV. (N. S.), p. 130.

Church wrote to me on the subject, and was so kind as to send me a specimen of the mineral to which he gives the name Woodwardite. This you will find, on making a comparison, agrees completely with my specimen already referred to as having afforded nearly the same results on analysis, as were originally obtained by Church. The false Woodwardites present the same kind of ripple marking as Church's homogeneous mineral, but they are usually of a pale green colour, and the mass is easily seen to be made up of distinct layers of various shades, from a full green to a faint greenish white colour. These are evidently compound deposits, and ought not to be labelled "Woodwardite." I know that many such specimens are in the market, but they can be easily avoided if the characters just mentioned be borne in mind.\*

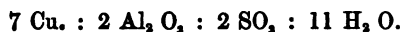
Turning now to the body recognised by Church, I may submit my analysis of the fine specimen before you, along with that of the original sample.

Both analyses are of the mineral dried at 100° C.

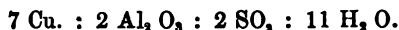
	Church.	Reynolds.
Cupric oxide, . . .	48.34—48.78.	
Aluminum oxide, . .	17.97—18.11.	
Sulphur trioxide, . .	13.95—14.10.	
Water, . . . . .	18.48—[19.01.]	by difference.

The two analyses agree very closely, and are satisfactory as proving the constancy in composition of the different samples of the deposit. Upon this point I was long in doubt, and felt some difficulty about regarding the compound as a definite one, and Woodwardite as a distinct mineral species. The analyses above given, however, strengthen the view that the species is a good one; moreover, Professor Church has lately informed me that he has succeeded in proving that the mineral is not a mere mixture, by means of the method of fractional solution so well known to chemists.

Finally, as regards the formula to be assigned to the mineral when dried at 100° C., Church gives the ratio as



My analysis is better represented by the ratio



The formula for the mineral may therefore be written:




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\* Traces of phosphoric acid and silica are usually present in the samples.

**XXI.—FURTHER OBSERVATIONS ON THE WELL AT ST. HELENS, LANCASHIRE. By PROFESSOR EDWARD HULL, F. R. S.**

[Read June 12th, 1872.]

THE author referred to a previous Paper entitled:—"On a Remarkable Fault at Rainhill, Lancashire," of which fault the slope was found to be two horizontal to one vertical, and having explained how this unusual slope had interfered with the water-supply from the well at Whiston, stated that the Town Council had since driven a tunnel in an easterly direction from the bottom of the well, as recommended by the author, and with excellent results, as would be observed from the following extract from a local newspaper which had been forwarded to the author by an influential member of the Town Council. The extract was as follows:—

*St. Helens Water Supply.*

The well sunk by the St. Helens Corporation, at Whiston, which for a long time was looked upon by a section of the Council as a failure, is now yielding a very considerable supply. It may be remembered that the fault was discovered in the boring at an angle, for which only one other parallel is known in England, and the supply then given was little over 300,000 gallons a day. The special water committee a few months ago decided upon tunnelling in the direction of the pebble beds, and the work has gone on since that time. A fortnight ago the water committee ordered the tunnelling to cease for four months, and the water to be sent to the town to relieve the scarcity; but the resolution had to await the ratification of the Council, and in the interim the work has been pushed forward. It is supposed the pebble beds have been reached, as there is a tremendous rush of water into the well, which the power of two engines is insufficient to drain out. Yesterday morning it was thought that a million gallons a day can be drawn from the well.

**XXII.—ON THE OCCURRENCE OF GYPSUM IN THE KEUPER MARLS, NEAR COAGH, CO. TYRONE.** By EDWARD T. HARDMAN, of the Geological Survey of Ireland, Associate Royal College of Science, Ireland.

[Read June 12, 1872.]

ABOUT three-quarters of a mile south of the town of Coagh, in the county Tyrone, and on the left bank of the Ballinderry river, during a fruitless trial for coal in the clays and shales of the Keuper series, under the impression that they were the shales or "metals" of the Coal Formation, the workmen came upon several irregular beds of Fibrous Gypsum.

Before I had an opportunity of visiting the place the work had been given up in disgust, but on going there later, it was plain from the amount of the mineral in the "spoil," as well as from the account given by those who had been employed in the undertaking, that a somewhat considerable quantity of gypsum must have been passed through. It was impossible to get accurate information as to the thickness of the deposit, those engaged in any boring operations in this part of the country being extremely careless of keeping proper records; but the following section given me by the borer a few days after the trial was brought to an end is probably approximately correct.

Sunk in	Test.
Clay, soil, &c., about . . . . .	10·0
Alternating red and green shales or clay in thin layers,	80·0
Red and green laminated shales, containing many irregular beds of gypsum, in large lumps varying from 1 to 5 inches thick, . . . . .	15·0
Total Sunk, . . . . .	105·0
Then bored in	
Red and green variegated shales, containing gypsum still in some quantity, but apparently not so plentiful as above, . . . . .	175·0
Total Bored and Sunk, . . . . .	280·0

The beds varied much in thickness in different portions. The specimens to be seen on the bank were sometimes slightly curved, the fibrous lines of crystallisation being often curved also, and mostly at right angles to the planes of bedding; but in some pieces the crystals which were then better developed, and acicular, lay parallel to the stratification. Some pieces were saccharoidal, but the greater number

were of fibrous structure. The workmen say, that in the fifteen feet sunk through, there was a very inconsiderable thickness of the clays free from gypsum, and its presence impeded their progress very much. Mr. Duff of Coagh, in whose employment the men were, told me that he considered the gypsum to be quite as abundant on leaving off, as when the boring was begun; that is judging from the whiteness of the sludge brought up. On the same authority, I learned that a specimen of talc was obtained during the sinking. Had a borer better fitted for such explorations been used it is possible that other minerals, such as rock salt, might have detected.

But for this trial it is hardly likely that the presence of gypsum would have been ascertained—however it might have been suspected, in this locality; for the gypsiferous beds where they rise to the south west are covered by dolerite, which having crossed the river some distance to the north of the boring, and there overlying hard white chalk, takes a sharp sweep round by the east and south, and crosses the river again, about fifty feet south west of the bore-hole, the strata in which the latter is sunk dipping to the N. W., at an angle of  $10^{\circ}$ . On the strike of these beds about 450 yards to the south-east, at a house on the east side of the county road leading from Kingsmill to Coagh, a well was put down to a depth of sixty feet in the red shales, in search of water, but no traces of gypsum were found there; this must be close to the boundary of the dolerite. Towards the north-west where the Keuper strata extend there is a thick covering of drift which renders examination difficult, but with careful search, the gypsiferous beds may probably be again discovered in that direction.

**XXIII.—ON SOME FORAMINIFERA IN THE CHALK OF THE NORTH OF IRELAND.** By Professor T. RUPERT JONES, F. R. S., G. S.

[Read November 13, 1872.]

PROFESSOR E. HULL, F. R. S., Director of the Geological Survey of Ireland, has kindly submitted for my examination four carefully mounted slices of indurated Chalk, and one of Chalk-flint, from the North of Ireland. Thus:—

1. B. 2. Chalk-flint, Moira, Co. Down.
2. B. 3. Chalk, Moira, Co. Down.
3. B. 14. Chalk, Dunwater Quarry, Co. Antrim.
4. B. 14.\* Chalk, Dunwater Quarry, Co. Antrim.
5. D. 2. Chalk, Co. Antrim, supposed to be near Belfast.

In examining these prepared slices of Chalk from Antrim and

Down counties, I have had the kind assistance of my friend Mr. W. K. Parker, F. R. S., and we recognize in the specimens various sections of perfect and fragmentary Foraminifera, of small size, as follow :—

1. *Lituola* ?
2. *Valvulina*.
3. *Dentalina communis*, d'Orb.
4. *Bulimina* (*Ataxophragmium*).
5. *Textilaria*: two varieties of the small *T. gibbosa*, common throughout the Chalk.
6. *Vernuolina pygmaea* (Egger).
7. *Globigerina cretacea*, d'Orb.
8. *Planorbulina*, small varieties related to *Pl. ammonoides* (Reuss).
9. *Pulvinulina Menardii*? (d'Orb).

Besides the visible organisms, there is a considerable proportion of amorphous Chalk, which we have been unable to resolve under the microscope into either Coccoliths or any other definite forms.

The slice of the associated Flint presents the same appearances as the Chalk, but less clearly, being, as is usual, that substance in a pseudomorphous state (silica after carbonate of lime), with the organic details less distinct.

The chief lesson we have learnt from these interesting sections of Chalk is, that the so-called "*Orbulinæ*," and "*Lagenæ*," which some Naturalists have observed in Chalk under the microscope may be, and probably are, only isolated chambers of *Textilaria*, *Planorbulina*, or *Globigerina*, whether broken off and scattered, or existing as single early chambers, either arrested, or unaccompanied by any chambers of later growth. At first sight, such separate chambers, seen in sections, certainly appear, if circular, as *Orbulinæ*, and, if oval, as *Lagenæ*; but to the practised eye the likeness is imperfect; something is wanted in the texture, contour, or relative thickness of the shell.

We are thus strengthened in doubts which we entertained of the assigned relationship of certain little Foraminifera figured by O. Heer, in his excellent work "*Die Urwelt der Schweiz*," (8vo. 1865), as *Lagenæ*, from the Sewerkalk and the Gault of Switzerland; and we feel assured that Kaufmann's "*Oligosteginæ*," (*op. cit.*) are also merely the early two or three chambers of *Planorbulina*, or *Textilaria*. Annexed is a synopsis of the Swiss Foraminifera above referred to, and their associates, with corrected nomenclature.

O. HEER: "*Die Urwelt der Schweiz*," 1865.

#### A. Die Polythalamien.

Pp. 193, &c. Polythalamien des Seewerkalkes, p. 194.  
P. 195, woodcuts, figs. 104 & 104.

1. Figs. 106, *a, b*, *Lagena sphaerica*, Kaufmann.
2. Figs. 107, *a, b*, *Lagena ovalis*, Kaufmann.  
[Fragments of *Textilaria*, *Planorbulina*, and *Globigerina*.]
3. P. 197, figs. 108, *a, b, c*, *Oligostegina levigata*, Kaufm.  
[Early chambers of *Planorbulina globulosa* (Ehr.) or *Textilaria globulosa*, Ehr.\*]
4. Pp. 197 & 198, figs. 109, *a-d*, *Textilaria globulosa*, Ehrenb.
5. P. 198, figs. 110, *a-e*, *Nonionina Escheri*, Kaufm.  
[This is *Globigerina cretacea*, d'Orb.]
6. Pp. 198 & 199, figs. 111, *a-g*, *Nonionina globulosa* (Ehr.).  
[These are *Planorbulina*: varieties between *Pl. ammonoides* (Reuss), and *Pl. ariminensis* (d'Orb.).]

B. Polythalamien des Gault, p. 199.

P. 200, figs. 112 & 113, Gault, with green grains and pyrites, containing :—

<i>Lagena sphaerica</i> , Kaufm.	} [Single and attached early chambers of <i>Planorbulina</i> , <i>Textilaria</i> , and <i>Globigerina</i> .]
— <i>ovalis</i> , Kaufm.	
<i>Oligostegina levigata</i> , Kaufm.	

*Nonionina Escheri*, Kaufm. [*Globigerina cretacea*, d'Orb.]

C. Polythalamien des Schrattenkalkes.

P. 202, figs. 114, *a-l*, sections of *Miliolæ*.

P. 203, figs. 115, *a-c*, *Orbitolina lenticularis*.

In another interesting work (P. Harting's "Die Macht des Kleinen," &c., translated from the Dutch), treating incidentally of the microzoa of the Chalk, we find some similar woodcuts of Foraminifera, which, on account of the analogy of the group exhibited, we here offer under similar conditions of nomenclature, thus :—"Die Macht des Kleinen sichtbar in der Bildung der Rinde unseres Erdballs," von P. Harting." Translated from the Dutch by Dr. A. Schwartzkopf, with an Introduction by Dr. M. J. Schleiden, 8vo., Leipzig, 1851.

Page 87, woodcut, fig. 39. Foraminifera obtained from a block of Chalk, taken out of the Drift of Friesland. Magnified 300 diameters.

1. *Planulina turgida*, Ehr. This is *Cristellaria rotulata* (Lam).
2. *Textilaria globulosa*, Ehr. Probably *Bolivina dilatata*, Reuss.
3. *T. globulosa*, Ehr. This is *T. sagittula*, DeFr.
4. *T. dilatata*, Ehr. Single chamber of *Globigerina*?

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\* For remarks on *Pl. globulosa* and *Textilaria globulosa*, see "Annals Nat. Hist.," for March, 1872, p. 224; for April, p. 284, &c.

5. & 8. *Textilaria globulosa*, Ehr. (Edge view and side view.)

6. & 7. *Rotalia globulosa*, Ehr. *Planorbulina globulosa* (Ehr.)

9. *Rotalia perforata*, Ehr. *Planorbulina vulgaris*, d'Orb, Young.

\*\* Fragments of *Rotalia globulosa*, and *Textilaria globulosa*. These, rightly regarded as "fragments," are single and attached early chambers of *Globigerina*, *Textilaria*, or *Planorbulina*. The single one is oval, and corresponds with "*Lagena ovalis*" of Kaufmann; the other three belong to Kaufmann's "*Oligostegina*."

In Eley's "Geology in the Garden" (1859), are some figures of similar minute objects from the Chalk and Flint of Essex. His pl. vii., figs. 39 & 39 c. (as indicated in the "Geol. Mag." for March, 1872, p. 124), comprise sectional views and separate chambers of *Textilaria globulosa*, *Planorbulina ammonoides*, and *Globigerina cretacea*.

We may add to this short notice of the microzoa of the Antrim and Downshire Chalk, as seen in Prof. E. Hull's sections, that, although the minute circular and oval rings seen therein, and in the similar sections of Swiss Chalk above mentioned, as well as in Harting's and Eley's figures, and in several plates of Ehrenberg's "*Mikrogeologie*," are not *Orbulinæ* and *Lagenæ*, yet these genera are not unrepresented in the Chalk; for Ehrenberg has unmistakably figured specimens of both kinds in his magnificent "*Mikrogeologie*" (1854). Thus we have shown lately in the "*Annals Nat. Hist.*," that several *Lagenæ* have been figured by him from the Cretaceous Limestones of several parts of the world; and *Orbulinæ* from the Chalk of Rügen in the Baltic, and of Volsk in Russia.

Although no new forms of microzoa occur to us in these slices of Chalk from the North of Ireland, yet, as Prof. E. Hull has already pointed out, in his notice of these interesting specimens at the Meeting of the Royal Geological Society of Ireland,\* on June 12, 1872, the fact of the hardened Chalk having been made to yield its secrets has a fascination for the Naturalist; and the adding of even already known Foraminifera† to the list of fossils found in Ireland is not without its use to the Palæontologist.‡

\* See the "Monthly Microscopical Journal," No. 45, Sept. 1, 1872, p. 142.

† A catalogue of the Foraminifera already known from the British Chalk, may be constructed from lists given in the "Geol. Mag." for November, 1871, p. 510, March, 1872, p. 125; "Quart. Jour. Geol. Soc.," vol. xxviii., p. 104, and "Annals Nat. Hist.," April, 1872, p. 301, together with Morris's "Catalogue Brit. Foss.," 1854, pages 33 et seq.

‡ Note by Mr. Hull.—The shells of the Foraminifera are formed of calcite, imbedded in an impalpable calcareous paste. With the micrometer scale some of the shells were measured, and found to range from 100<sup>th</sup> to 600<sup>th</sup> of an inch in diameter.

**XXIV.—NOTES ON THE GEOLOGY OF THE HARTZ. By P. S. ABRAHAM,  
B. A., B. Sc., &c. Plates VIII., IX., X., XI.**

[Read November 13, 1872.]

AFTER a diligent search, I have been able to find but very few Papers relating to the geology of the Hartz in any of the British Scientific Publications. In 1839, Messrs. Sedgwick and Murchison made a long communication to the Geological Society of London concerning the geology of central Germany and the Rhenish Provinces, and a part of this especially relates to the Hartz. It is printed at length in the Transactions.\* A further paper by Murchison and Morris upon Thuringia and the Hartz was read to the same Society some years afterwards; and it appears in the Journal of the Geological Society, vol. xi.† Lastly, Sir P. de M. Egerton has written about the contents of certain calcareous caves at Rubiland and at other places in the Hartz.‡ When we consider that the rock formations of the Hartz are of historical interest to the geologist—for it was here that Werner especially attempted to illustrate and prove his celebrated aqueous theory,—that their mineral resources have been known and developed for over a thousand years; and finally, that they are so very easy of access—being at the present time within a 30 hours' journey from London—it is a matter for surprise that they have been so little visited by English geologists. Nor, indeed, has the subject been yet thoroughly worked out by the native scientific men.

Beyond an excellent, although rather meagre little handbook by the accomplished Bergrath Dr. von Groddeck, Director of the Clausthal Mining Academy, a tourist with a hammer has really scarcely anything to guide him in his rambles. It is true that Prediger and Roemer have published a geological map, which can be obtained with ease in the locality, but I soon found it to be very inaccurate and unreliable. One on a larger scale is now, however, in course of preparation by Dr. von Groddeck, and we may well expect that this will leave nothing to be desired. The visits of Sedgwick, Murchison, and Morris to these mountains must necessarily have been hurried, and their labours appear to have been chiefly directed to the identification of the strata and to their consideration from a wide and general aspect. In this, they did valuable work; and they were the first to show that the formations of the Hartz did not lie piled up around the granite

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\* Transactions of the Geological Society of London, 2nd Series, Vol. VI., p. 295.

† Journal of the Geological Society of London, Vol. XI., p. 409.

‡ Proceedings of the Geological Society, Vol. II. p. 94.



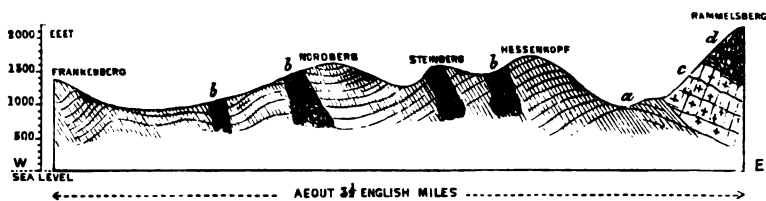


Fig. 1.

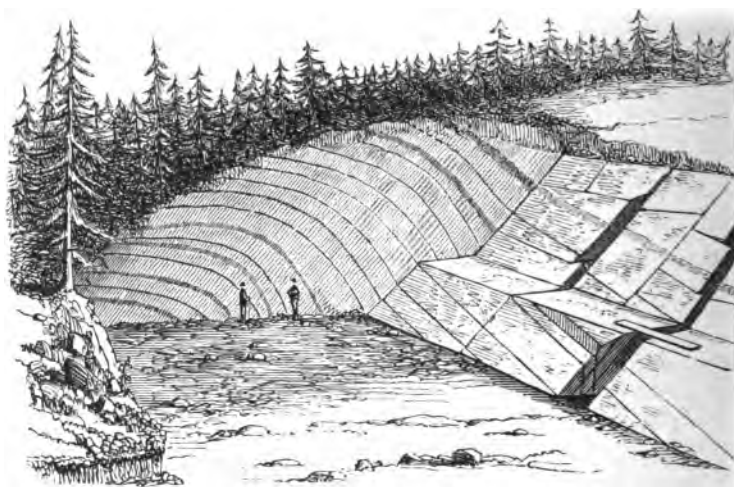


Fig. 2.

mass of the Brocken, and that they were not conformable to the beds of the surrounding plains,—all of which had been previously believed and used as arguments by the followers of Werner. The fact is, that the general strike of the rocks of the neighbouring flat country is N. W., while that of the up-raised beds, forming the high ground, is on the whole N. E. by E. In this they afford a most excellent example of the great unconformability between the secondary and primary systems. The north-easterly strike of the primary rocks of the Hartz is parallel to the strike of the similar rocks in Thuringia and in the neighbourhood of the Rhine. Moreover, the greater number of the ridges and undulations forming the Hartz mountains run in the same direction, and therefore *across* the axis of the main chain—this fact seems to me interesting and remarkable.

The portion of the Hartz with which I am best acquainted is that in the neighbourhood of the picturesque old town of Goslar. Here the mountains—or hills as they would be called in Switzerland, for none of them are much over 2000 feet above the sea level—are chiefly in the form of ridges with an average N. E. lie. Their section (Plate VIII. fig. 1) shows a well-rounded outline, and they are nearly all closely covered with artificially planted pine forests. The ridges to the south and south-west of the town are composed of argillaceous slate, which is at present worked for roofing purposes and slabs in a most primitive manner. In texture the slate is somewhat coarse, rough and micaceous, and in colour a greyish black. There are no stripes whatever of a light tint, but the appearance is often slightly spoilt by the presence of bands of a little different texture: nevertheless, it splits into large and thin plates, which can be easily dressed, sawn, or planed. It is considerably less brittle than the slate from Wales, and from the fact of its being quite free from pyrites and carbonate of lime, it is perfectly durable—some of it, indeed, has lain upon the Goslar buildings for 150 years, and still serves its purpose. In these characters it contrasts favorably with the slate from the Rhenish districts. The specific gravity of a sample I determined to be 2.7, and I found that a piece immersed in water for 48 hours, and wiped dry, had gained scarcely anything in weight. One of the most remarkable points connected with this slate bed is its excellent quality—and consequent economic value—to within a few feet below the surface of the soil. The bedding in general is very much contorted: this is well shown by the stripes and bands that are to be seen on the side walls of most of the quarries (Plate VIII. fig. 2). In no part of the bed has the thickness of the rock been exposed, although in one of the quarries a depth of 200 feet has been reached. The cleavage is remarkably well developed and tolerably regular throughout the whole extent of the layer; its strike is N. 80° E., and its dip, on the average, 40° to 50°, a little E. of S. However, I find that as one proceeds from W. to E. the cleavage plane dips gradually at a higher angle. Thus, at Frankenberg, the most westerly opening that I visited, the dip of the split is under 35°; at the Nordberg quarries, about a

mile further east, it becomes  $45^{\circ}$ , while in those on the Rabenkopf and Hessenkopf, the most easterly points, it is  $50^{\circ}$  to  $55^{\circ}$ . Am I to take this to be an example, on a small scale, of Darwin's "fan-shaped" cleavage? The master joints of this slate deposit are extremely powerful and constant, with a direction nearly N. and S., and a westerly dip of about  $85^{\circ}$ . In a quarry on the Nordberg one of these joints forms a wall of some 70 or 80 feet in every direction. In one of the quarries on the Steinberg, I noticed one or two powerful tabular joints about  $15^{\circ}$  from the horizontal.\* There are, moreover, well-developed cross courses running E. and W., and dipping S. at  $60^{\circ}$ . Although there are all these natural advantages for quarrying the rock economically, the native workmen scarcely make any use of them. The plan they chiefly adopt is to cut artificial "foot joints" by means of the pick at vertical intervals of about 6 feet. Besides the great waste of time and material, it is of course quite impossible to obtain large slabs from the small galleries thus formed. In the best quarries in Wales, the galleries are often 70 feet apart, and every possible advantage is taken of the natural joints. During my stay in the district, I could find very few traces of the former life of the deposit: fossils of Devonian character have, however, been found in the partings of the bed. Chiefly upon the evidences of one genus, *Bactrites*, this layer has been identified with the Wissenbach slate of the Rhenish provinces. There are a few trappean dykes traversing the slate: they are not all of the same mineralogical composition; thus one which is exposed about 300 yards south of Frankenberg is of Diabase Greenstone, another proceeding N. W. across the Nordberg and Todberg is an amygdaloidal Porphyry,—the weathered portions presenting a peculiar honeycombed appearance. On the northerly slope of the Steinberg a considerable mass of Diabase underlies a stratified deposit of hornstone.

One of the spots that especially interested me, in the vicinity of Goslar, was the valley of the Ocker, a small river that eventually empties itself into the Weser. The first thing that one notices on entering this valley from the north, is that the bed of the stream is crowded by granite pebbles and boulders, which become of greater size as one proceeds up the valley. The boulders are soon of such a size—many of them of some tons in weight—and are situated so far up the slopes on each side, that the first idea is, that we have here the morass of a former great glacier. I looked diligently for ice marks, but could see none; and I soon found that the causes which have the effect of scattering huge blocks of rock on the slopes and on the bed of the river are now at work, and are slowly but surely altering the contour of the adjoining granitic mountains. The quaternary rock, of which these

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\* In a figure in Messrs. Sedgwick and Murchison's Paper, especial stress is laid on these tabular joints—I cannot say that I found them numerous.

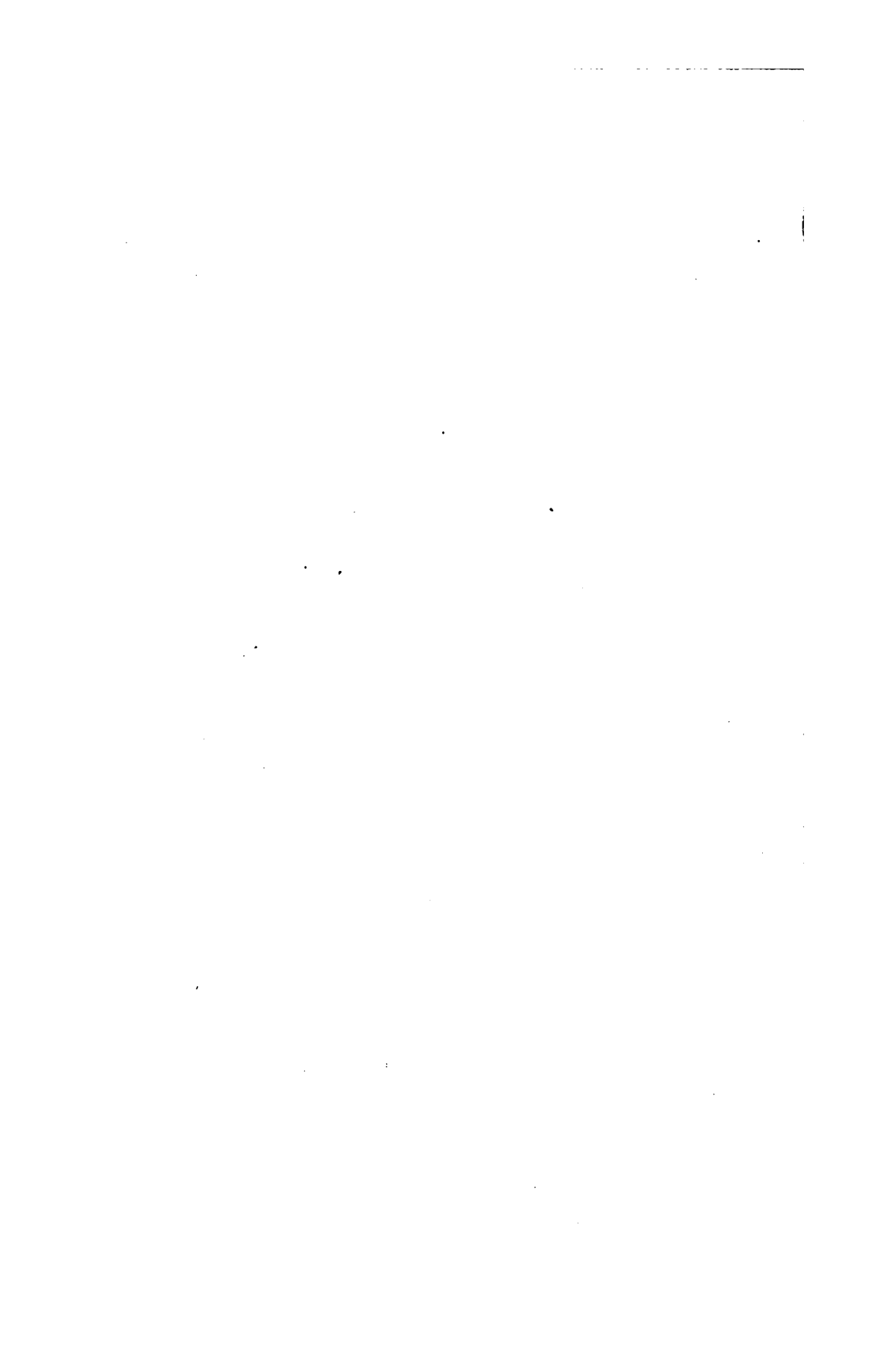


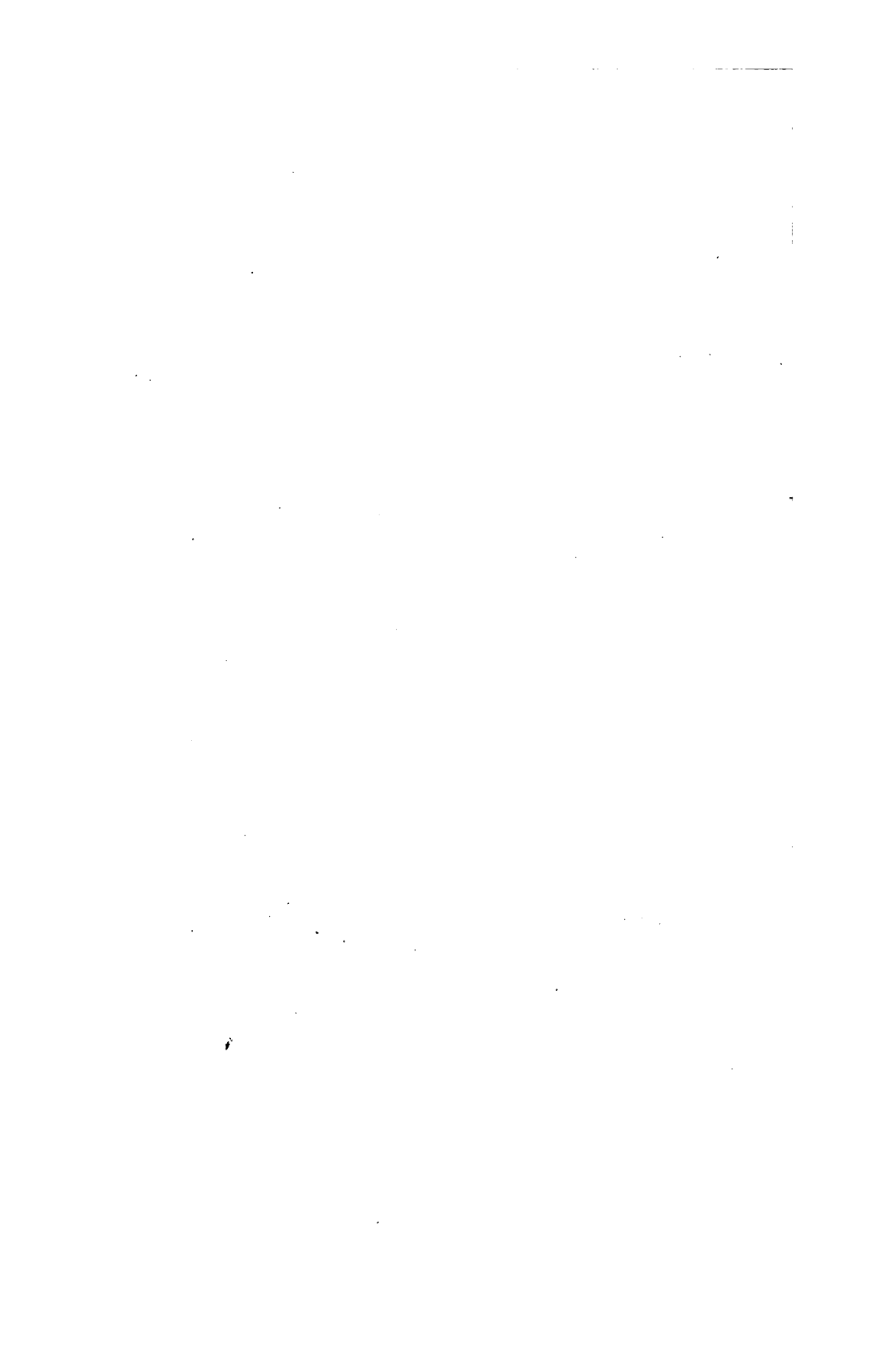


Fig. 4.



Fig. 5.

TO ILLUSTRATE MR. ABRAHAM'S PAPER ON THE HARTZ.



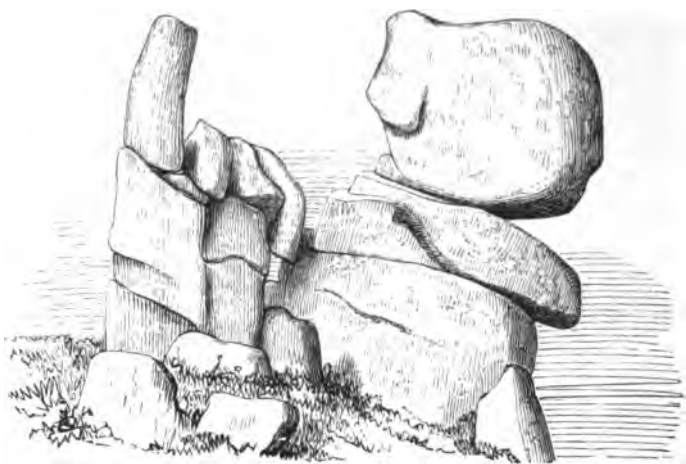


Fig. 6.

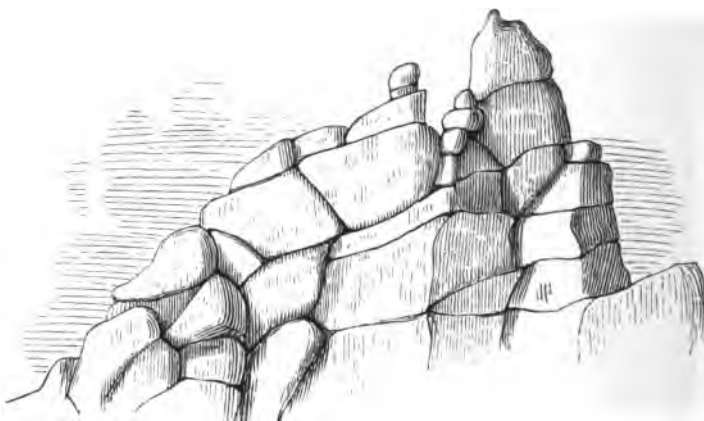


Fig. 8.





Fig. 10.



Fig. 11.

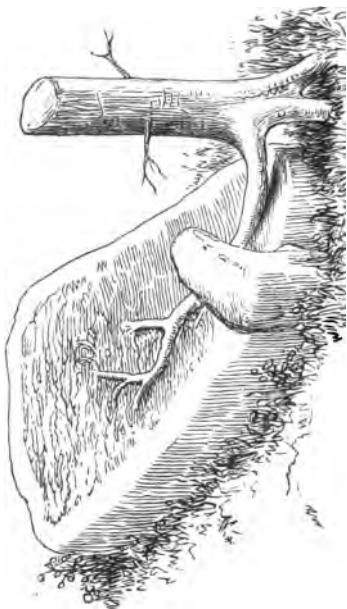


Fig. 12.

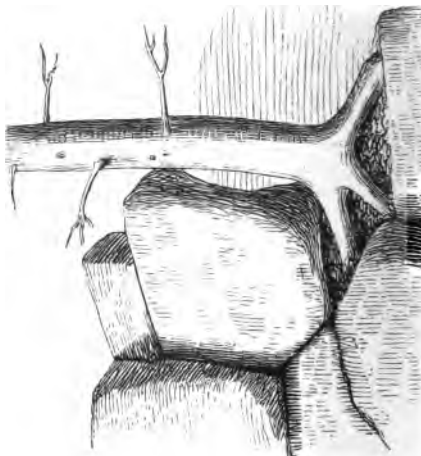


Fig. 13.

TOGELASTHAT, NIE. ARGUMENTS. FAGER ON THE HANCOZ.

are composed, contains silica, orthose, oligoclase, and a little greenish-black magnesia-mica: crystals of black tourmaline are very numerous. The colour *en masse* is a greenish-white, but the oligoclase seems to be readily decomposable, and the resulting soft stone becomes of a brownish or reddish tinge. Powerful joints, which become more numerous and better developed sometimes in a N. W., at others in a N. E. direction, intersect the whole, and I remarked that whenever one of these systems became especially apparent, then the axis of the valley beneath becomes parallel to the system. Moreover, besides the more vertical joints, a more horizontal system exists, dipping at a low angle more or less westerly. The development of these evidently affects the direction and amount of the slope. This influence of joints on the contours of hills and valleys, although occasionally alluded to, appears to me to have been insufficiently dwelt upon by geologists. All over the sides and upon the summits of these mountains are scattered the most fantastic piles of immense boulders. Some of these are over 30 feet in height, and form conspicuous objects in the landscape. Others again are deep in the forest, away from pathways, and are not to be seen until one climbs quite up to them. Many of the large heaps have received names, of course, like a great number of things in the Hartz, connected with the lower regions, thus we have the "Devil's Pulpit," the "Devil's Sofa," the "Devil's Armchair," &c. It is quite clear that the contiguous surfaces of the blocks in these piles are undergoing a slow decomposition; that the joints are becoming gradually looser; and, in consequence, the cohesion of component rocks less and less. Sooner or later the upper portions must either slip off or topple over, and roll down the mountain side. And this is not mere theory, for I hear that every now and then a boulder does fall, and comes crushing down the hill until quietly deposited at the bottom. The rough sketches (Plates IX. and X.) are intended to illustrate some of the above points. It would appear that while the surrounding rock has been decomposed, has fallen down in the manner indicated, these heaps have the longer resisted,—but they are yet to follow in their turn: when the atmospheric agencies have sufficiently done their work, gravity will come in and lower the whole.

Among other interesting points that I observed in this valley was the rôle that the trees played either in hastening the decomposition, or assisting in the preservation of the granitic rock. These mountains are completely clothed with magnificent pines, one to two feet in diameter, and from 60 to 100 feet in height. It is curious to remark that the trees should so flourish when the only mould existing is that formed by the fallen leaves and decayed branches—in some places nearly two feet in thickness. Constantly a tree is seen springing from a bare block of granite, the roots either curling round or entering the soil beneath the block (Pl. XI., fig. 10), or entering into the joints which have thereby become enlarged (Pl. XI., fig. 11). In one case a root is seen growing upwards, and after breaking off, as it were, a large splinter of the rock, it opens out

in some damp moss that is lying on the slightly concave upper surface of the block (Pl. XI., fig. 12). In the above examples the general effect of the roots must be taken as hastening on the decomposition of the mountain; but in Pl. XI., fig. 13, a tree has grown up by the side of a shady-looking mass, and it is evident that the rigidity of the wood, temporarily at least, prevents the whole from coming down.

Lastly, in this valley I observed that some of the rocks lying in the bed of the river are next to others that appear to fit on to them. It seems probable that the partial or inceptive joints have become fully developed since the falling down of the block.

There are a great many forcible examples near Goslar of the great denuding power of rain; for instance, if the geologist looks northwards down from the Rammelsberg on to the plateau immediately beneath, he will see the surface deeply furrowed into channels six or eight feet deep. There are at first but few of these, but they soon open out into a great number, which again become concentrated into one or two that ultimately enter the bed of the Gose stream. Except after heavy rain they do not serve as watercourses.

At the lower part of the north-easterly slope of the Nordberg lies a thick bed of stratified drift, composed of a sandy matrix with fragments of schist of various sizes, and here and there pieces of greenstone. This, too, has been deeply and extensively channeled by rain action. The end of one of the ridges between two furrows was dug into and carted away a few weeks ago, and I was astonished to see that the cross section exposed by the men exhibited the particles of schist, and the finer materials deposited in a sharp inclinal fold, the axis of which is horizontal. As the whole mass is scarcely properly consolidated, and as the components are so evidently similar to the rocks of the adjoining mountains, it is difficult to conceive of any contortion having taken place in the bed.

XXV.—A DESCRIPTION OF TWO VEDDAH SKULLS FROM CEYLON. BY  
ALEXANDER MACALISTER, M. B.

THE Museum of Trinity College has recently received from Mr. Sharpe, of the Ceylon Civil Service, two very fine Veddah skulls from Ceylon, which are of importance, as the race to which they belong is one of the interesting and problematical so-called aboriginal races of the Island.

The Veddahs as they exist at present consist of several tribes, and are divided into two sets, Village Veddahs, who are stationary and agricultural, and rather the more civilized, and Forest Veddahs, who are wild, living by the chase, usually naked, strictly endogamic, have no idols, nor semblance of outward worship, and who pay little respect

to the remains of their dead. They are not an intelligent race, and are comparatively harmless, not inclined to fight unless when provoked. They describe themselves as being the descendants of the original inhabitants of the Island, or Yakoos, who were subjugated by the wiles of Wijeya Singha and his followers, who, banished from Bengal, settled here B. C. 545. Their language is similar to that of some of the Hill tribes of Continental India, having no affinity to Cingalese or Pali.

The skulls of this race have been described by Mr. Busk, in the Proceedings of Linnæan Society, vol. vi., p. 166 (1862): four skulls of this race were in Mr. Busk's possession, one in the College of Surgeons Museum, and eleven in the Museum of Dr. Barnard Davis (*Thesaurus Craniorum* p. 130). They are all remarkable for their small size and lightness, and for their great proportional height; they are exceedingly narrow, long and oval, dolicho-cephalic, orthognathous, and phœnozygous. One of Dr. Davis' female skulls has an exostosis on the left frontal and one on the right parietal bones; and two, a male and a female, are synostotic, producing the varieties of form known as cylindro-cephalism, and kline-cephalism, respectively: the female skull is interesting as presenting the latter form with an open spheno-parietal suture. From these skulls I have compiled the accompanying table of measurements:—

	Internal Capacity in oz. of said sp. gr. [1·425]	Cranial index.	Circumference.	Fronto-occipital arch.	Inter-mastoid arch.	Length.	Breadth.	Height.
Mr. Davis' male Batticaloa, . .	64	0·72	19·7	14·2	13·8	6·9	5·0	5·0
„ female, . .		0·68	19·8	14·8		7·3	5·0	5·0
„ Badulla female,		0·71	18·8	14·0	13·1	6·7	4·8	5·1
„ „ male, .			19·2					
„ Batticaloa female, . . .	70	0·69	19·6	14·4	13·7	7·1	4·9	5·2
„ Batticaloa female, . . .	56	0·75	17·8	13·7	13·1	6·2	4·7	5·2
„ Batticaloa female, . . .	65	0·78	18·7	14·0	13·8	6·6	5·2	5·3
„ „ „	64	0·70	19·8	14·7	13·0	7·4	5·2	5·0
„ Ouvah male, .	81	0·68	20·9	16·0	15·2	7·6	5·2	5·6
„ „ female,	59	0·66	18·7	14·2	13·0	6·9	4·6	5·0
„ Tribe? female,	72·5	0·76	19·2	14·4	14·5	6·7	5·1	5·5
Trinity College, ♂	70	0·75	18·6	13·9	13·1	6·6	5·0	5·5
„ „ ♀	65	0·72	19·5	14·8	14·0	7·2	5·0	5·9
Average . . . .	66	0·73	18·6	14·0	13·6	6·8	4·9	5·3

The average cranial capacity of 55 *Hindoo* skulls is 84 cubic inches, Dr. Morton gives it as 81. The Aboriginal tribes have all a much smaller capacity: thus of two *Yenadies*, the capacities average 72 cubic inches, while of 39 English skulls, the capacities average 90, and of 30 Irish = 88.

This microcephalism is very well marked in the specimens under notice.

The female skull is orthognathic, dolicho-cephalic, cryptozygous, has a trace of the frontal suture, a trace of a diseased spot on the right side of the frontal, has a peculiar coronal suture, straight above and below, and very complexly denticulated for its middle third, this arrangement I found in some Irish skulls its upper surface is convex nearly to ridging. The sagittal suture is carinated with coarse tothing, and a left parietal foramen exists. The centre of the parietal bones are 4.25 apart. There is a wormian bone in the left side of the posterior point of convergence of the sagittal and lambdoidal suture, and the latter suture is not very complex, and has one wormian bone near its junction with the occipito-mastoid suture. The occipital crest is well marked and the under lips of the foramen-magnum are unusually prominent. There are two very remarkable lingulæ on the exoccipital bone, which project outwards and backwards.

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XXVI.—PRESIDENTIAL ADDRESS. By ALEXANDER MACALISTER, Professor of Zoology and Comparative Anatomy, T. C. D.

[Read February 12, 1873.]

GENTLEMEN,—Nine years have elapsed since a President of this Society delivered a valedictory address on the evening of his vacating the Chair, and though I fear it is presumptuous in me, one of the youngest of those who have been honoured with the distinction of presiding at your meetings, to revive the former usage, yet I think it a pity to allow our original custom to pass into desuetude. I am deeply sensible of the honour which you have done me by electing me to the Presidential Chair, and I fear that my short-comings while in office have been many; I am happy, however, to be in a position to congratulate the Society on its continued prosperity, as testified to by the report and statement of accounts to which we have all listened with so much pleasure.

I cannot follow in the footsteps of my predecessors in presenting before you a resumé of the work which has been done in the different walks of geological science since the last summary of this nature was brought before your notice in 1863; that would be far too tedious and arduous a task; for geology, though among the youngest of the sciences, yet on account of the interest attaching to its details, and the economic importance of its study, has made of late years greater advances than

any other branches of cosmical science. And I think we may take some credit to ourselves in this respect, for in the patient and earnest search after truth, which is the true aim and end of every scientific association, Fellows of this Society have not been one whit behind those in connexion with our companion Geological Societies, and in past years we have been rewarded by a very gratifying success both in the amount and interest of new and important scientific facts which we have been the means of bringing forward, and have published in our Journal. Verily the history of the past of this Society, with the associated names of Jukes, Griffith, Portlock, Lloyd, Oldham, &c., should stimulate those of us upon whom it has fallen to support its interests, to increased exertions in the cause of our science.

One distinguishing feature of the work of this Society has always been its extent and diversity of range. Mineralogy has claimed a fair share of our attention, and the papers of Apjohn, Kane, Haughton, and Reynolds on this subject are solid contributions to this branch of geological science, and truly the recent advances in chemistry have given us a new and more engrossing interest in this department. Now that we know that the same laws regulate the combinations in the inorganic and organic worlds, that there is but one chemistry, and not a separate science for organic and for inorganic compounds, it is interesting to see that on two bodies and their compounds hang all or most of the varying forms of nature. Professor Haeckel has, and with a show of reason, spoken of the organic world as the realm of carbon, and we may with nearly equal truth regard the mineral world as the realm of silicon. What carbon is in the first, that silicon is in the second: in the one we find the exhibition of molecular forces in compounds of the greatest instability, and their properties depend thereupon; in the other we see the opposite condition of varieties of forces exhibited in compounds of the greatest stability. In this connexion it is interesting to notice the parallelism of property in these two bodies, how that as the one has its crystalline form, often with curved faces, its graphitoid and amorphous states, so has the other; as the one has its stable saline compounds with oxygen and the metals, so has the other; and finally, as the one has its hydrogen compounds, its unstable alliances whose properties constitute the properties of organic bodies, so has the other its singularly curious hydrogen compounds like silicic hydride, chryseone, leukon, chloroleukon, its silicic ethers, chloroforms, and iodoform compounds, in which carbon is replaced by silicon, like siliconyl,\* silicic mercaptans, &c. All these interesting bodies are only now coming to our knowledge, through the labours of Wöhler, Buff, Friedel, Ladenburgh and Reynolds, and in some of their allies possibly may inhere the latent properties of a second organic world.

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\*  $\text{Si C}_8 \text{H}_{19}$  = Nonyl ( $\text{C}_9 \text{H}_{19}$ ) in which one equivalent of Si has replaced one of C.

This was delivered before the publication of Professor Reynolds' interesting lecture on the Silicon Alcohols, delivered at the Royal Institution, London.

But in another and equally interesting aspect the science of mineral geology has made very great strides of late; the microscope has been pressed into the service of our science, and is now being recognised as one of the most important implements in the geologist's armamentarium: to it we owe the expansion of a comparatively new field of work, namely Petrography. This science may be said to have come into existence in 1858, when Mr. Sorby read his celebrated paper on crystals, before the Geological Society of London, as previous to that time the microscope had only been used in investigating the properties of precious stones, of individual minerals, and of fossil woods, but had never been systematically applied to the study of the histology of rocks. Since 1858 a large number of workers have crowded into the field and are actively engaged in following up this means of research; among these I may name Sandberger, Vogelsang, Zirkel, Tschermak, Allport, Fischer, David Forbes, Lasaulx, Roth, Drasche, Behrens, and I rejoice to say that with these I may couple the name of our President elect, Professor Hull. As long ago as 1838, Dufrénoy\* used this instrument in the examination of volcanic ashes, but he carried his investigations no further. Mr. Sorby† in his papers from a study of crystals artificially formed under different conditions, laid down the following propositions:—

1st. That crystals enclosing cavities containing water only were formed by deposition from aqueous solution.

2nd. Crystals containing only stone cavities or glass cavities have been formed from a material in a state of igneous fusion.

3rd. Those containing at the same time water cavities and stone or glass cavities are such as have been formed from a mass of melted matter in contact with water, under great pressure.

4th. The amount of water contained in the cavities may be used as a datum from which to deduce the temperature at which the rock was formed, since the vacant space is the measure of the contraction of the fluid on cooling.

5th. If only empty cavities, or air spaces exist, the rock or crystalline material has been formed by sublimation, unless the cavities are gas cavities, inflated by the product gases of heated rock.

6th. If few such cavities exist, the rock or crystalline mass has been slowly formed, if many, it has been quickly formed.

7th. When no cavities occur, the crystalline mass has either been formed with extreme slowness, or else is the result of the cooling of a perfectly homogeneous material.

These may be looked upon as having formed the basement propositions of the science of Petrography, a science which, in this country,

\* *Annales des Mines, Troisième Série, Tome XII, p. 355.*

† *Quart. Journal Geol. Soc. Lond. 1858, Vol. XIV., p. 463, Edin.—New Phil. Journal, 1861. Leonhard and Geinitz, Neues Jahrbuch, 1861, S. 769.*

has as yet made little progress, while in Germany it has probably attracted a greater share of scientific attention than any other branch of Geology. Mr. Sorby applied these principles to the study of rock materials in veins, of rock-salt, selenite, calcite, quartz, which he showed often contained true water cavities, containing chlorides or free hydrochloric acid, and therefore were certainly the products of deposition from aqueous solution. He also showed that in the case of granite veins the formation of bands of pure quartz and mica may be due to the removal of a part of the alkali from the felspar by the agencies of water and heat, as Bischof has proved, and thus led on to the study of the genesis of granites, which he also believed to be aqueo-igneous.

In 1864, the eozoon controversy increased the interest in the science of Micro-petrography. It will be remembered that in 1858, Mr. M'Culloch, of the Canadian Geological Survey, found in the Upper Laurentian rocks of Canada, peculiarly shaped masses of rock which were recognised as possibly organic by Sir W. Logan, and the practised eye of Professor Ramsay also detected an organic facies in the mass. On the suggestion of several geologists, Dr. Dawson, of Montreal, undertook the microscopic examination of the masses, and detected in them a structure which he described as foraminiferous, and described the material as a new species of rhizopod of gigantic size, with the habit of a *Polytrema*, and with an acervulous mode of chamber growth, the chamber walls were composed of lime and the cells, stolon cavities, and tubular systems had become infiltrated with reusselaerite, loganite, pyroxene or serpentine; particles, fibres, and grains of graphite had been detected in the neighbourhood of these chambers, a presumptive evidence of an organic origin, and alga-like markings and scolithus-like burrows, likewise co-existed. Our highest authorities on foraminifera, on examining the specimens coincided in Dr. Dawson's view, but the publication of these memoirs occasioned a controversy, which, if it did nothing else, turned some attention to the study of micro-petrography, and some at least of the writers displayed a very considerable practical ignorance, not only of the appearance of sections of large foraminifera, but also of sections of common forms of rock and of the interpretation of rock-forms as seen by the microscope. With a larger experience of micro-petrography will come, I believe, a full conviction of the true organic nature of Eozoon Canadense. The mineral composition of serpentine has lately been carefully studied by an eminent authority, Tschermak (Sitzb. K. K. Akad. in Wien, 1867, p. 22).

In 1863, Professor Zirkel, of Lemberg, published his first paper on this subject of micro-petrography in the *Verhandlung der k. k. Geologischen Reichsanstalt Jahrgang 13*, s. 8, which he calls *Mikroskopische Untersuchung von Gesteinen u. Mineralien*. In this he confirmed and extended Mr. Sorby's investigations, described the contents of the glass and other cavities in granites, felsites, pitchstones, artificial and natural glasses, obsidians, &c.

In another paper, published in the "Neues Jahrbuch" (1866, p. 769), Professor Zirkel describes the microscopical structure of the mineral combinations in the lavas from two volcanic islets at Nea Kammeni, near Santorin, in the Ægean Sea. In these he describes feldspathic crystals, often klinobasic, irregularly arranged in the glassy pitchstone-like matrix. He also shows the presence of small glass spaces; masses, oval or irregularly lobed, containing little globular crescentic or oblong cavities, or else multitudes of little pores or minute cavities, like so many tiny dots, through the vitrified spot. In 1867, this same author published his valuable *Lehrbuch der Petrographie*, a book that deserves every commendation that can be bestowed on it, and which is a monument of the care and study which Professor Zirkel has bestowed on this branch of science, of which, if he be not the father, he is certainly the nurturer. As I suppose this book is in the hands of every one who takes an interest in petrography, I need say no more regarding it. In the same year, 1867, Professor Zirkel published a letter entitled "Dunnschliffe echter Basalte," in the "Jahrbuch" (1867, p. 81), in which he showed that this rock was not a complete congeries of interlocking crystals, but consisted of crystals embedded in a pale yellow or grey-coloured mass, which does not exhibit the parti-colours of a double refracting body with the polariscope, and is probably a glassy body of the same nature as the enclosed particles in the ento-crystalline glass spaces.

Mr. Sorby, in 1863,\* pointed out the importance of the microscopic evidence as to the metamorphic nature of mica slate, showing that thereby the ripple structure and the original granular clay and sand-nature might be detected, and has illustrated thus the threefold condition in which this rock has existed,—as a sedimentary deposit, as a cleaved and compressed slate, and finally as a metamorphosed crystalline schist; and Zirkel, in 1872, showed how specimens of altered sandstone could be distinguished by the microscope from pearlstones.

Professor Tschermak has distinguished himself in the field of micro-mineralogy by his discoveries regarding the distinction of albite or orthoclase,† by their behaviour when exposed to polarized light; as an equally important companion discovery, he has also found that with polarized light sections of hornblende crystals manifest a decided dichroism while augite crystals do not, an important test when applied to basalts and other rocks to distinguish these two closely allied minerals. In this field of work, however, as far as simple minerals are concerned, he has been preceded by Brewster, who described the optical properties of many minerals, greenockite, opal, diamond, fluid cavities in topazes and other stones, lepidolite, and the zeolites. Other writers have also been engaged in this line of work of late years—too

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\* Q. J. Geolog. Soc., 1863, vol. xix., p. 405.

† Sitzungsab. der K. K. Akad. in Wien. 1865, s. 566.

many to notice in detail. If the theory favoured by the experiments of Gustav Rose, Berthier, and Nöggerath be correct, that the genetic distinction between hornblende and augite arises from the latter having been more suddenly crystallized from the magma, and the former more slowly, such a distinguishing character as this may be of the greatest use in discriminating these minerals when their crystallization and cleavage planes are obscure, and may throw light on the conditions of the genesis of some rock masses.

In 1868, Zirkel again published a paper, in Poggendorf's *Annals*, vol. 131, p. 298, on the microscopic combinations of minerals in phonolite, specimens of which he selected from twenty-six localities. These he found to consist of nepheline, hornblende, nosean, magnetite, and sanidin, and the last element was evidently ordinarily the last to crystallize from the component magma, as its larger crystals enclose crystalline particles of nepheline, hornblende, magnetite, and, more rarely, nosean, whose solidification probably was second last. Yet another paper\* on vitrified and semi-vitrified minerals, and one on leucite, and leucitiferous rocks, were published by the same author. In the second of these papers he called attention to the known fact of the curious constancy of the presence or absence of this felspar in some volcanic rocks, while the microscope has detected it in some lavas in which it has otherwise not been noticed. He found, on examining sixty-three specimens of obsidian, pitchstone, pearlstone, &c., that they all consisted of a glassy basis, whose elements did not display any separableness; and these contained needle-like crystals, which he called belonites, when colourless, clear, and trichites, when black hair-like, and he defined the conditions under which these were formed in opposition to the larger crystals of felspar or other materials. This paper, which is too long to quote or summarize, is one of Zirkel's best and most suggestive.

In 1869, Professor Sandberger published a series of observations on the microscopic structure of nephelinite, on which mineral in the same year Zirkel published a paper of great value.

In this little sketch of the history of petrography, I should not omit to mention the interesting little manual for beginners by Kenn-gott, published in 1868 at Leipzig, although no new facts in the microscopy of rocks are there enumerated.

In 1872, Professor Fuchs has published a microscopic examination of the rocks of the Pyrenees, a subject upon which Zirkel has also a Memoir in the "*Zeitschrift der Deutschen Geologischen Gesellschaft*, 1867," p. 68, in which he discusses the structure of the ophite of that region. Fuchs in this paper has given us an exceedingly good account of the microscopic structure of rocks in different stages of metamorphism.

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\* *Zeitschr. d. Deutsch. Geol. Gesellsch.* 1867, s. 377.

In 1871, Hagge published at Kiel a work on the microscopic structure of gabbro-hypersthene and serpentine, in which from a great variety of detail of structure several points are made conspicuous, especially the prominence of the olivine as a mineral ingredient and labradorite in dark needles.

In 1872, Professor Zirkel described the microscopic structure of a sparkling variety of obsidian from Cerro de los Navajos in Mexico, which in oblique light exhibits a remarkable greenish yellow colour. This stone on slicing displays a great variety of uncommon, thin, mostly pointed ovoid plates of microscopic minuteness; at first sight these might be taken for hollow spaces, their borders are often rounded at the end, often running together at the end. That they are not cavities is obvious from their smallness and fineness of outline, whereas were they spaces, the difference between the refraction exponent of obsidian and of a space, would give the appearance of a rim, these are sometimes sinuous in their margins, sometimes appear broken across or cracked across, their greatest observed length is 0.06 mm. One might anticipate their thinness by the look of their broad surface and by the fact that every change of the focussing of the microscope brings new plates into view. The thickness seems tolerably equal, thinning suddenly at the margins and ends, to these lamellæ the peculiar colour apparently is in a manner due. Whether in other sparkling stones, such or allied appearances may be found, or no, is an interesting point, as also is the determination of the exact nature of these somewhat oat-shaped bodies and the signification of their practically exact parallelism.

In another paper in the same series Zirkel has detailed the combinations of minerals in a basalt from Hamberg near Böhne, on the Hessian frontier. This basalt shows a remarkable mixture of augite, melilite, olivine, leucite, nepheline, hauyne, and magnetic oxide of iron; it is a free felspathic basalt, and the most interesting features found are that the olivine crystals are rich in glass cavities and fluid cavities whose contents from their sparkle and mobility Professor Zirkel supposes to be liquid carbonic acid. Another feature is that the augite crystals seem to surround with a peculiar predilection the beautifully sharp leucitohedra of that variety of felspar, a fact noticed in other leucite-bearing basalts, from whence it is inferred that the olivine was the first of the minerals to separate from the magma. In connexion with this specimen, Professor Zirkel directs attention to the petrographic similarity of mineral constitution of this North German basalt and the Italian one of Vultur, near Melfi, and in this connexion it is and will be of the deepest interest to compare and collate the facts learned by petrographic study and those observed in field geology.

In a sandstone in contact with basalt, Zirkel has found sphaerulites, small glassy, often globular, granules, some of which have concentric spaces or bodies within, and in other vitrified masses he describes black spider-like markings. These glass bodies may be the result of particles forced in by pressure, and something similar might be looked for with

interest in sandstones, in contact with igneous rocks; appearances like some of these found in metamorphic rocks, have led some micro-petrographers to express an unfavourable opinion of Eozoon.

Professor Zirkel has also used the microscope in the examination of the curious striped varieties of felspar, whose chemical natures has been studied by Gerhard,\* who has showed some of them (Perthite) to be lamellar interleaving of orthoclase plates and white albite. Now as in some the laminae are so thin as to defy mechanical separation, for purposes of analysis, the microscope comes in here as a useful aid to the mineralogist in the recognition of the elements of these striped felspars, and he has found in Perthite that a section when viewed by polarized light, exhibits the contrasted parti-coloured bands of the albite, and the monochroic orthoclase. Some of the minutely striped felspars, however, he has shown not to owe this colouration to a difference in composition, but to a different molecular arrangement, the lamellae being alternate plates of normal pure felspar substance, and of a material composed of needles of a pale yellow colour and elongated lobate granules, together with rows of microscopic dark rimmed pores of exceedingly small size, giving the appearance of densely concentrated and closely connected strange images succeeding each other like strings of pearls. This lamination he compares to that noticed in the trachytes of the Drachenfels. Its causation will be a curious study.

Mr. Allport, one of the few British geologists who have done work in this field of micro-geology has given to us several papers on the structures of pitchstones, felsites, dolerite, &c., and has promised further publication on the subject. In the Geological Magazine, (VIII. p. 448, and IX., 536), he has described the igneous rocks of Arran. Among other points which he has discovered and elucidated, he has recorded the finding of pitchstone microscopically porphyritic with quartz and felspar crystals in a clear glassy matrix containing straight belonites, arranged in streams, belonitiferous cavities occurring in the quartz crystals, while no such cavities existed in the matrix. In another specimen he found a bipectinate grouping of acicular black crystals in a colourless glassy base, and these he resolve into pyroxene belonites studded with grains of magnetite. In a pitchstone boulder containing a fine-grained basalt, he found in the latter part, quartz crystals, containing portions of the basaltic matrix in which they are imbedded. Curious considerations of the epigenesis of these minerals will here occur to the thoughtful mind. Mr. Allport has also noticed that the base of pitchstone is a homogeneous glass, not exhibiting double refraction, while the base of felsites and porphyrites is invariably doubly refracting, from which he infers that pitchstones were formed under conditions which were unfavourable to crystallization in the matrix, while felsites were formed under conditions which allowed the commencement, but checked the progress of crystallization. He also expressed his opinion that there is

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\* Zeitschrift der Deutsches Geologischen Gesellschaft, Bd. xiv., 1861, s. 151.

no mineralogical nor structural difference between the felsites of palæozoic and the trachytes of tertiary age.

In volcanic ashes from Etna, Zirkel has found felspar grains, acicular fragments of augite and magnetite, some of the fragments of felspar including glass cavities; this is interesting, for in lavas, trachytes, and basalts, the felspar element contrasts with the augitic or hornblendic in the fewness of its foreign enclosures. The ashes of Etna and Hecla are almost identical and nearly devoid of leucite. Those of Vesuvius contain colorless particles of leucite and green augite, the leucite is rich in included brownish glass cavities, and is in the form of sharply angled leucitoedra; magnetite, sanidin, and tear-like drops of porous glass clinging to the acicular augite crystals; some of these become developed at one end, and present peculiar bipinnate shapes, varieties of which have been figured by Zirkel (Taf. 1. fig. 7). In general the lavas and ashes of any volcano have according to him the following differences.

1. In the special multiplicity of glass enclosures in the crystals of the latter.
2. In the extraordinary filling of the crystals with foreign bodies in the latter.
3. In their containing a predominance of the glass substance.
4. In these and the crystals containing an unusual number of dark rimmed gas spaces.
5. In the existence, in the ashes, of peculiar flocks or heaps of microlithes of augite and magnetite pressed together.

One of the most interesting bearings of the study of micro-petrography is the light it throws on the paragenesis of minerals, a study of the deepest interest in connexion with researches on geological actions, and one on which we have the advantage of possessing several good masterly works; besides the paper of Breithaupt, who first systematically called attention to the subject, there is "facile princeps," of all the books, Senft's *Krystallinischen Felsgemengtheile nach ihren Mineralischen Eigenschaften*, &c., published at Berlin in 1868.

I should apologize for having detained you so long in thus reviewing the literature of Micro-geology, but in excuse, I plead that the subject is little known and much misunderstood, and one in which a vast amount of work yet remains to be done. In the lines along which Rosenbusch, Lasaulx, and Fuchs are working, much is yet to be done, that is in the correlation of Petrography and Petrology, of the structure to the position of the rock mass.\*

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\* I add a list of other papers on this subject of Micro-geology so as to make this bibliography as complete as I can.

FISCHER. *Kritische Mikroskopische Mineralogische Studien*. Freiburg, 1869.

ROSENBUSCH. *Petrographische Studien an den Gesteinen des Kaiserstuhles*. (Neues Jahrbuch, 1872, Hft-2, S. 134, &c.)

LASAULX. *Petrographische Studien an den Vulkanischen gesteinen der Auvergne*, *ibid.*, 1870-72.

ZIRKEL. *Basalt gesteine*, 1870.

Another branch of geological work, for which I think we may claim some credit as a Society in the past, is in the study of the more recent Tertiary and post Tertiary deposits, especially as these are to be found in Ireland, and when in connexion with this branch I mention the name of Mr. Close, that in itself is sufficient to justify our claim, and this also is a part of our science where much remains yet to be done, for in the entire range of stratigraphical geology, few portions are in greater disorder than that section intervening between the now forming surface layers and the true Pliocene formations of the age anterior to the Norwich Crag. We can hardly call any classification satisfactory of the superficial sands and gravels, drift, eskers, &c., at least it is very difficult to secure any basis whereby we can determine the contemporaneity of the parallel series of different countries. As far it goes, we welcome the time-classification of Mr. Boyd Dawkins, which is, like every other communication of that distinguished geologist, a solid contribution to our geological knowledge. According to this scheme there were three distinct but blending portions in the Pleistocene age:—

1st. The age in which Pleistocene immigrants had disturbed but had not supplanted the Pliocene mammals, corresponding to the Norfolk Forest bed, the deposit at St. Prest, near Chartres, the beds described by Bryce in Ayrshire, underlying the drift.

2nd. The period of the retreat or extinction of the Pliocene mammals, during which the deer of the Pliocene disappear, and which is represented by the Thames lower brick-earths of Erith, Crayford, &c., by the older deposits of Kent's Hole, the Cave of Baume, and a river

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Prof. Rosenbusch has promised a Manual of Micro-petrography which I have not yet seen.

VOGELSANG. Sur les crystallites, Archives Néerlandaises. 1873.

Professor Hull has also published Micro-geological Reports on several Irish granites in the Memoirs of the Irish Geological Survey.

JUSTUS ROTH. Beiträge zur Petrographie des Plutonische gesteine. Berlin, 1869.

LASAULX. Beiträge zur Mikromineralogie. (Poggendorf's Annals, Bd. 144).

ZIRKEL. Über die Mikroskopische Zusammensetzung der Thonschiefer und Dach-schiefer. (Poggendorf's Annals, *ibid*, p. 319).

BEHRNS. Über Grünsteine. (Jahrbuch, 1871, p. 460. Sitzungsberichte der K. Akad in Wien, 64, 1871)

VIVENOT. Micros. Untersuch. des Syenits von Blaussko. (Verhand der d. Geol. Reichsanstalt 1870, p. 336.

INOSTRANZEFF. Über die Mikrostructur der Vesuv.-lavas. 1872. Jahrbuch der K. K. Geol. Reichsanstalt, 1872, Bd. xxii., s. 101.

A. STEIZNER, Professor in Cordova, Buenos Ayres. Petrographische Bemerkungen über Gesteine des Altai Leipzig, 1871, *ibid*. Untersuchungen in Gebiete des Sächsischen Granulit Gebirge, Jahrbuch, 1871, p. 244.

ZIRKEL in Zeitschrift der Deutschen Geologischen Gesellschaft, 23, Hft. 1, p. 244, gives a description of Arran and its Volcanic rocks compared with those of the North of Ireland, also of Mull, Skye, Staffa. He recognises the two-fold ages of the Basalts of Trotternish, the oldest being directly antecedent to the Oxford clay, and the newest being Tertiary.

DRASCHKE über Eklogite, Tschermak's Mineralogische Mittheilung.

ROSENBUSCH. Ueber einige Vulkanische Gesteine von Java, Berichte über die Verhandlungen der naturforschenden Gesellschaft zur Freiburg, Bd. vi., hft. 1, 1873, p. 77.

deposit at Auvergne, an age during which the *Elephas meridionalis* and *Rhin. struscus* have retreated.

3rd. The period of the true Arctic mammals, the Arctic and grizzly bears, the cave hyena, the megaceros, the musk ox, corresponding to the Pleistocene brick-earths, gravels, and later ossiferous caves of Britain, to the reindeer, auroch, mammoth and cave bear periods of Lartet, to the mammoth and reindeer periods of Dupont, to the true glacial or lower boulder clay period, possibly to the middle sands and gravels, and upper clay as well.

Mr. Dawkins maps out Europe during the Pleistocene into three climatal zones, one south of the parallel of 43°, one north of 53°, and one between these lines. The northern zone has never been traversed by the southern forms of animals like the *Rhinoceros struscus*, *Eleph. meridionalis*, and *antiquus*, the southern was not penetrated by the northern forms like the reindeer, and in the middle the groups co-existed. That man existed in the middle and latest of these periods is demonstrated, his existence in the middle bringing thus his origin anterior to the glacial epoch.

The period of the Esker-formation, during which at least 19 of the mammals became extinct in Britain, was probably that which followed the third period of Mr. Dawkins; and the period of the Clyde bed formation, and of the high-level gravel formation was either parallel or immediately subsequent, corresponding to Mr. Dana's Champlain period and to Dr. Dawson's Leda beds.

In Ireland our Pleistocene and post Pleistocene deposits have been carefully studied. What Professor Haughton has done for our Irish Tides, that Mr. Close has done for our Irish Glacial phenomena, and in his papers he has published detailed observations on the general glaciation of Ireland, and the local glaciation of Dublin, Kerry, Iar Connaught, &c., and he has demonstrated, that the agent producing these phenomena was none other than land ice, and that the ice-covering was of considerable thickness. That in other places, sea-ice may have deposited a boulder clay is quite probable in view of the facts noticed by Dr. Dawson, who has noticed the transport and deposit of a present day boulder clay on the coast of Nova Scotia, possibly some part of the English and Scottish upper boulder clay may be of marine origin; the Irish glaciating agent, however, was plainly land ice. Mr. Dawkins' classification is very good as far as it goes, but only local, as it can only be used in his middle zone, and it does not contemplate dealing with the most confused of all deposits, the post glacial gravels, peats, raised beaches, cavern deposits, and silts, which are of the deepest interest to us, as being the sources from whence our knowledge of pre-historic man is derived. Could we arrive at a definite chronological classification and correlation of these, it would save us from an indefinite and confused discussion concerning the relative age of the human race: we know that man lived as far back as the middle of Mr. Dawkins' three periods, that is, before the commencement of the severe cold, but this is only interesting to us as a possible limit; we know very

little of these Palæolithic men, except that they were a rude and savage race who occupied the globe for a period which in length surpassed the combined Neolithic, Bronze, Iron, and Historic ages.

In other departments of stratigraphical geology, a great and important amount of work has been done from time to time by Fellows of this Society, and to one branch of this specially would I for a moment direct your attention. Our distinguished and lamented colleague, Mr. Jukes, having entered into the labours of Sir Richard Griffith, in the study of those rocks of the south and west of Munster which form the base of the carboniferous system, some years ago applied the knowledge thus acquired to the unravelling of the difficult questions regarding the proper conformation of the rocks of Devon, and came to the following conclusions, that the culm measures were the equivalents of the coal measures, and the so-called Devonian rocks were the equivalents of the carboniferous limestone, carboniferous slates, and yellow sandstones of Ireland. In 1842 these resemblances were pointed out by Sir Richard Griffiths, and they were put forward in detail by Mr. Jukes in 1866, and as we all know opposed strenuously by the leading English geologists headed by Mr. Etheridge. Having found that in the south of Ireland the carboniferous limestone was separated from the Old Red Sandstone by carboniferous slate, whose thickness often varied in the inverse ratio of that of the carboniferous limestone, he proposed as a theoretical interpretation of the North Devon rocks that the rocks of North Foreland, Croydon Hill, and N. W. of the Quantocks represented the top of the Old Red Sandstone to which succeeded the carboniferous slates of Lynton and Ilfracombe, then the succession is interrupted by a supposed fault with downthrow to the north, stretching from the north corner of Morte Bay, in a direction east by south, then succeeded a band of old red sandstone brought to the surface by the fault, and the carboniferous slates again. This theory of a fault was laughed to scorn by the English geologists, who mainly relied on the evidence derived from Palæontology which however was imperfect as one of the limestones, that of Cannington Park classed as Upper Devonian by Mr. Etheridge has been shown by the observations of Bristow and Woodward,\* and by the corals found in it by Mr. Perceval,† to be carboniferous, probably the representative of the Bristol mountain limestone.

There is another fact noticed by Mr. Hall in his description of the Syenite mass at Hestercombe, near Taunton, that it is most nearly connected to that of Lundy Island, since the run of the Palæozoic rocks is east and west because the least resistance of igneous rocks is along the line of strike. Mr. Woodward in a recent paper in the "Quarterly Journal of Science" (1873, No. 37, p. 108), has directed attention to this fact, as it would lie very much in the line of Mr. Jukes' fault.

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\* Geol. Mag. 8, p. 504.

† *Ibid.* 9, p. 94.

Though the evidence brought by our revered former colleague was really very important it has as yet failed to convince some of those who have had no opportunities of study in the south of Ireland, but it and other considerations have led to a strong doubt on the mind of the geological world as to whether the Devonian and the Old Red Sandstone are really contemporaneous, and we find Mr. Godwin Austin and Professor Phillips expressing their opinion that the Devonian rocks form a sub-system intermediate between the Old Red Sandstone and the carboniferous, in fact an older member of the carboniferous, a group to fill up the ante-carboniferous age of Professor Haeckel.

The department in which our work during the past few years has perhaps been most deficient, is that of Palæontology. While kindred societies have been spending their strength mainly upon this science, we must confess that with the exception of the papers of Mr. Baily, Prof. Traquair, and a few others, we have done little, and no part of Geology requires a more philosophical treatment; owing to the imperfection of the specimens, to the small number examined, and perhaps to other personal causes, Palæontology has suffered more than any other part of Biology from the mania for species-making to which so many of the specialists in Biological investigations are so much addicted. The Brachiopods for example have been unnecessarily sub-divided at the hands of such species-makers, and any one who patiently examines large series of individuals of any of the better marked genera cannot but come to the conclusion that most of the so-called species are but varieties, indeed the larger the collection of individuals examined the smaller will be the number of species which the philosophic naturalist will make. Take for example the genus *Spirifer* (upon which some exceedingly interesting remarks have been made by Professor James Hall, the distinguished American geologist, in the "Proceedings of the Philosophical Society of Philadelphia," for 1866), and in a study of any large group of specimens, we will see that from one end to the other there are so many shades and gradations that it is hard to define any of the species within rigid limits, one must either give a name to every variety or else assign arbitrary limits to the application of each name. I know of no branch of Natural History which will so soon convert a thoughtful man to the theory of the community of descent of, at least, all the species of a genus, as the study of the fossil Brachiopoda.

The remarks regarding the want of definiteness of specific characters is capable of a much wider application; the discovery for instance in Kansas of a cretaceous bird with amphiœslian vertebræ, published lately by Professor Marsh, of a bird with a reptilian tail like *Archæopteryx*, of a reptile with the proximal part of the tarsus anchylosed to the tibia (as in a bird), and a bipedal progression like *Compsognathus*, of a flying reptile without teeth in the front of its jaws as *Rhamphorhynchus*, and of birds with true teeth like those described recently by Marsh, of cetaceans, with double fanged teeth with cuspidate crowns like *Saurocetes*,—these and such like show us that the animal kingdom

presents us with no hard lines of demarcation between one form and another, but, let us proceed in what direction we choose, we are gradually led on, creeping on from point to point, until we have travelled over a goodly number of forms to the limits of the kingdom; and such a study shows us the richness of variety in the Creation, for it is not in any one or two lines that forms vary, but it is in every conceivable direction, and as many of these opposite varieties must necessarily have been inconsistent with the well-being of the species, they passed into extinction, and thus the record of the rocks is to us a story of a continued struggle of varying forms with external conditions, those suitable to their surroundings living on while those inharmonious perish, and as conditions periodically changed owing to cosmical laws, so the faunæ of the successive periods are historic of the adaptive changes in life-forms to suit them to the external arrangements of nature, and hence it is that such beings as are simplest in their relations survive in the greatest variety, and specifically live the longest, while those which are the most complex in relation cannot bear even the most trivial change in their conditioning. Thus we see among the Ostracode Crustacea and Foraminifera such a wondrous variety of individual form in all periods, and such a remarkable specific longevity.

In nature there is a wondrous harmony between the teachings of Palæontology and those of Embryology, a harmony which can only be intelligibly interpreted on the hypothesis that the one is a condensation of the other, that as in Embryology we have a record of the development of the individual, so in Palæontology we have the story of the development of the species, and in both cases we see the same laws, the same progress from the general to the special, so that we may, in the words of the great French anatomist, regard Palæontology as a fixed Embryology. One of the most interesting of the new points in this connexion is the study of the relation of the Trilobites to the other groups of the Arthropoda, for which we have so much materials in the labours of Dohrn, Packard, Woodward, Barrande, and Burmeister. The recent observation on the embryology of *Limulus* have shown us that its earliest appearance in the egg is that of a Naupliiform larva (Packard), on a little further development it exhibits what we may call a trilobitoid stage closely resembling *Trinucleus* and *Sao*, having at first a form with a simple cephalic and caudal plate, and then subsequently developing numerous intermediate body rings. Dohrn has also shown the remarkable analogy between *Belinurus* and *Prestwichia*, and the nearly mature embryo of *Limulus*. Thus the Trilobites occupy an interesting position in the phylogeny of crustacea, as they start from the primitive (or Naupliiform embryo), and developing along a line parallel to the Phyllopoda, give off the stems of the Isopoda, Stomapoda, and Decapoda, lines to which we are conducted by the Devonian *Præarcturus*, the carboniferous *Uronectes*, and *Anthropalæmon* respectively, and not only are the trilobites thus ancestral to these, but they and the Merostomata must have had an early common starting point from which the prototri-  
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bites were developed in one direction, and *Neolimulus*, *Prestwichia*, *Belinurus*, *Limulus*, *Hemiaspis*, and *Pterygotus* in other directions.

Dohrn has been led by his researches to separate from the main body of the crustacea all those which have no true Nauplius stage, no metamorphosis further than an increase in the multiplicity of their segments, and thus he constructs a group like Hæckel's *Gigantostaca*, composed of *Xiphosura*, *Eurypterida*, and *Trilobitida*, intermediate between Crustacea and Arachnida, and, like all other intermediate groups, precedent to them in point of time.

Before leaving the crustacea, it is interesting to notice how far the gaps between the living genera have been filled up by fossil forms—thus Mr. Woodward's new *Hemiaspis*, with its separate cephalic, thoracic, and abdominal divisions, is a connecting link between the *Xiphosura* and the *Eurypterida*, coming with *Pseudoniscus* and *Exapinurus* of Nieszkowsky, after *Belinurus*, *Prestwichia*, and *Limulus*, on our way to the *Eurypteridæ*.

In the view of all these advances we may look forward hopefully to a new session's work, to do our share in the advancement of our science, before which a glorious prospect is opening. It is along the lines which we have just now been reviewing that the geology of the future may be expected to make the most important advances. A perfected chemical science will enable the mineralogist to establish definite laws of the paragenesis of compounds in the inorganic world, while a perfected Palæontology will, sooner or later, show to the biologist a glorious panorama of evolution. For the full fruition of this hope we must still continue to work and wait with unabated zeal, and though many years, yea centuries, may elapse before this consummation of science be arrived at, even at the railroad speed of our present day's work, yet we may, in view of the progress of the last twenty-five years, be sanguine that "what we have done is but earnest of the things that we shall do."

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XXVII.—ON THE MICROSCOPIC STRUCTURE OF THE LIMERICK CARBONIFEROUS TRAP-ROCKS (METAPHYRES). By PROFESSOR EDWARD HULL, M. A., F. R. S. Plate VII.

[Read March 12, 1873.]

DR. MACALISTER, in his able Presidential Address, has furnished the Society with a summary of the work done, principally by German petrologists, with the object of determining the mineral constitution and structure of plutonic, metamorphic, volcanic, and other rocks, by the aid of the microscope. Forbes, Sorby, and Allport amongst ourselves have also represented British petrologists in the same field, but perhaps have not been sufficiently forward in giving the results of

their labours to the world. As representing the Geological Survey in this country, I may mention that I have been fully alive to the great benefits to be derived from the use of the microscope, and nearly one hundred specimens of sliced rocks have already received a certain amount of scrutiny, and the results have been noted. These results will be from time to time inserted in the Explanatory Memoirs which are published along with the Geological Maps; and the Memoir issued last year (1872) on the Geology of portions of Counties Down and Armagh, near Banbridge,<sup>1</sup> will be found to contain the first of these published series of observations on the microscopic structure of some of the rocks of the district.

Amongst the rocks which I have had opportunities of microscopically examining, the basalts and dolerites of the North of Ireland and the older melaphyres of County Limerick have received some attention; and I purpose in this paper to institute a comparison between these two classes of rocks, which may be considered as the representative augitic lavas of the Miocene and Carboniferous periods in Ireland.

*Authors of Papers on the Limerick Trap-rocks.*—The geological structure of the Limerick Carboniferous basin has been described by several writers. Of these may be specially mentioned Mr. Weaver,<sup>2</sup> Dr. Apjohn,<sup>3</sup> Mr. Ainsworth,<sup>4</sup> Sir R. Griffith,<sup>5</sup> and Messrs. Jukes, Kinahan and Wynne.<sup>6</sup> From the description, often exceedingly full, which these authors have furnished, it is now understood that the trap-rocks of the Limerick Carboniferous basin are themselves of Carboniferous age. As Mr. Kinahan observes, these traps and associated ashes form two great deposits, occupying well-defined geological horizons; the lower coming in a little above the base of the Lower Limestone, immediately over the cherty beds that are taken as the division between the Lower and Upper Limestones; and the upper, a little below the basal shales of the Coal-measures.<sup>7</sup> There seem to have been two principal out-pourings of lava from sub-marine or subaerial vents, accompanied by eruptions of ashes and agglomerates, the materials having been strewed over the adjacent seas; and Mr. Jukes suggests that some of the detached bosses of trap are to be regarded with great probability as the volcanic foci or "necks" of these old Carboniferous craters.<sup>8</sup>

<sup>1</sup> Expl. Memoir to accompany Sheet 48 of the Maps of the Geol. Survey.

<sup>2</sup> "On the Geological Relations of the East Coast of Ireland." *Trans. Geol. Soc., Lond.*, vol. v., by Thomas Weaver, M. R. I. A.

<sup>3</sup> "Observations on the Trap District in the Co. Limerick." *Journ. Geol. Soc. Dub.*, vol. i. p. 24 (1832).

<sup>4</sup> A further Account of the Limerick Trap-rocks, by William Ainsworth (1833), with Map.

<sup>5</sup> Geological Map of Ireland, with reference (1839).

<sup>6</sup> Explanations of the Geological Survey Maps, Sheets 143, 144 (1860).

<sup>7</sup> *Ibid.* Sheet 44, p. 24.

<sup>8</sup> *Ibid.* Sheet 143, note p. 10.

*Names and Mineral Characters of the Rocks.*—Though these trap-rocks present considerable variations in appearance and texture, they are more or less basic (with one exception), and probably augitic. The terms they have received, however, from various authors are numerous, such as "Greenstone," "Basalt," "Porphyry," "Amygdaloid," "Spilites," "Diorite," and "Melaphyre." Let us hope that the term "Greenstone" will in course of time—and chiefly through the aid of the microscope—fall into oblivion; at present it can only be regarded as a word intended to conceal our ignorance.

Assuming the words "greenstone" and "diorite" to be synonymous, and intended to designate a crystalline rock composed of hornblende and felspar, it is questionable whether such a rock is actually to be found amongst the Limerick trap series, although crystals of hornblende do sometimes occur as accessories.

As stated by the officers of the Geological Survey, "These rocks are of dark and light green, dark and light blue, or reddish colours, the latter being often due to decomposition. Their texture is generally compact, or fine-grained, with crystals of felspar widely dispersed through the mass; other crystals are rare, and some even of those traps, which from their dark colour have been called 'greenstone,' seem almost entirely felspathic. Some of these rocks pass imperceptibly into porphyries and amygdaloids, which have many varieties in the different localities in which they are met with." Mr. Jukes adds in a note, "A detailed chemical investigation into the composition of these varying trap-rocks would be very interesting and instructive. Without it, it is impossible to guess the proportions in which the felspathic are mingled with the augitic or hornblendic minerals; or even to decide on the nature of the felspars themselves."<sup>1</sup>

It is exceedingly interesting to observe that similar rocks occur in great force amongst the Lower Carboniferous beds of Scotland, forming the ranges of hills which bound the Coal-field of the Clyde basin along both its northern and southern borders. They have apparently been erupted from volcanic vents at the same, or nearly the same period of geologic time as the Limerick traps themselves, while in the "toad-stones," or basaltic amygdaloids of Derbyshire, we recognize the English representatives. Thus it appears that in the regions now occupied by the S. W. of Ireland, the centre of Scotland, and the centre of England, volcanic craters, in all probability submarine, were in active operation, pouring forth over the bed of a highly populous sea sheets of lava, and vomiting forth ashes and agglomerates amongst forests of crinoids and tribes of molluscs and corallines. When, in 1868, I brought over some specimens of these

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<sup>1</sup> Explanation to Sheet 44, p. 9.

rocks from Scotland, and showed them to Mr. Jukes, he at once recognized their similarity to "the Limerick trap-rocks."

The case here mentioned is an instance of the homogeneous character of igneous rocks of the same age over considerable tracts of country, which seems to me to have important bearings on the question of the internal fluidity of the earth below the solid crust.

*Microscopic slices.*—Of the twelve sliced specimens which I have examined, taken from various places over the district, all but one belong to that general group of augitic rocks which may be conveniently named "melaphyres," and which are the representatives in Mesozoic and Upper Palæozoic times of the more recent basalts and dolerites. In general structure these Limerick melaphyres consist of a glassy, or colourless felspathic base,<sup>1</sup> in which are imbedded crystalline grains of augite, magnetite (or titano-ferrite), pseudomorphs of olivine occasionally, with a considerable infusion of chlorite and calcite. Sometimes large crystals of banded felspar occur, as in the specimen from Herbertstown. In all cases, however, the base is a glass, or a glass mixed with colourless triclinic felspar, and the augite only occurs in distinct grains, and is by no means abundant at any time. The dark green colouring of the rocks is due to the generally large number of magnetite grains and the abundance of chlorite or epidote, generally the former. I now proceed to give a brief account of the individual sliced specimens which I have examined:—

(1). *Specimen from Herbertstown* (Lower Trap-band).—Base a glass with cavities and tubes, passing into crystalline granular triclinic felspar, with light-brown crystalline grains of augite, large crystals of banded felspar, magnetite grains, and chlorite filling in cavities, and in distinct grains.

*Augite.*—Some of the crystals are very well formed, and inclose magnetite grains. They are of a pale brown colour, much fissured, and are locally numerous.

*Felspar crystals.*—The large crystals porphyritically imbedded, show, with polarized light, the banded structure and the fine lines characteristic of one of the triclinic group.

*Chlorite.*—The chlorite occurs as filling in the interstices in the base, and between the crystals, but sometimes as distinct grains, with the rounded or oval form resembling grains of olivine. It is not improbable it has replaced this latter mineral. In some places it assumes the vermiform structure which is not uncommon, and it has every appearance of being a "secondary" mineral, infiltrated into the rock after consolidation.

(2). *Specimen from Roxborough* (Lower Trap-band).—This is an exceedingly interesting specimen, containing well-formed crystals of

<sup>1</sup> I presume the glass base is the amorphous form of the felspar.

augite, olivine, triclinic felspar, and (which is rare) hornblende, the latter large and well defined (figs. 10 and 11), the whole imbedded in a base blackened by magnetite. The substance of the crystals is generally entirely changed, and replaced by a yellowish mineral (epidote or chlorite) and calcite. The base seen with the quarter-inch power (200 diams.) is a colourless or yellowish glass, full of magnetite crystals, and having long slender prisms of triclinic felspar imbedded therein; also nests and pockets of a yellowish-green mineral with radiate fibrous structure, probably epidote. This mineral—sometimes without structure—frequently replaces the substance of the augite, olivine, and hornblende.

The specimen is remarkable for the large well-formed crystals of hornblende, porphyritically developed. Generally the walls of the crystals are filled in with secondary minerals, such as epidote and calcite; but there is one crystal retaining the original brownish-fissured substance of the hornblende itself. This crystal enabled me to apply the test of dichroism, which Tschermak and Allport have both proposed for the determination of hornblende as against augite. The mineral is more strongly dichroic than any specimen of hornblende I have yet examined, while the forms of the crystals are of themselves sufficiently distinct for identification. But for this specimen, I would have doubted the occurrence of hornblende amongst these rocks.

(3). *Specimen from Rathjordan* (Upper Trap-band).—Base a colourless glass, sometimes tinged green, with multitudes of belonites crossing each other in all directions, and numerous elongated cavities (fig. 9). This felspathic base is darkened by crystalline grains of magnetite, and contains crystals of augite and long prisms of felspar. The crystals of augite and felspar are generally replaced by chlorite (?).

*Augite*.—The crystalline grains of augite are all more or less replaced by chlorite; but the forms are decisive, and are made very plain by polarized light.

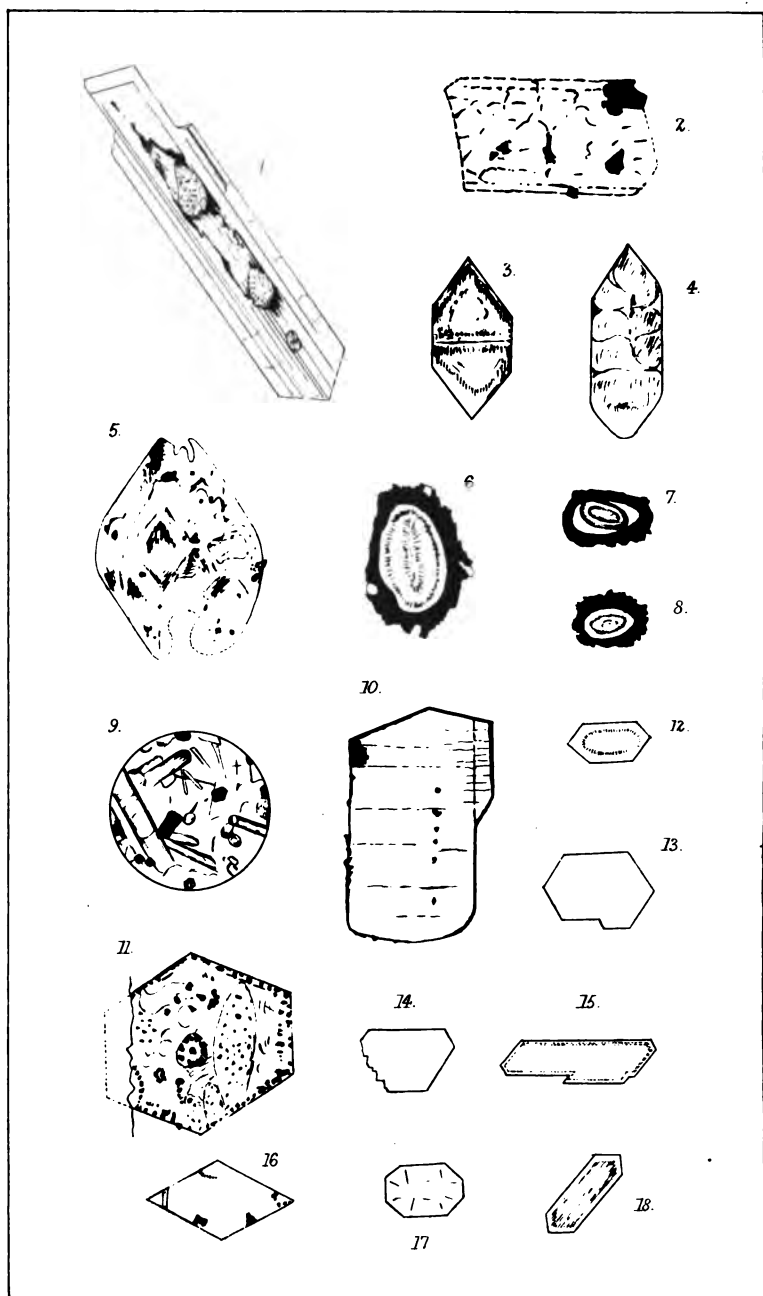
*Chlorite* (?).—Light greenish mineral, with fibrous structure, filling cavities or interstices; as well as replacing the material of the augite and some of the felspar crystals.

*Calcite*.—With polarized light, the peculiar smalt-blue and opalescence of calcite is apparent, filling fissures and interstices in the felspathic base.

*Cavities*.—With the quarter-inch power, magnifying 200 diams., numerous cavities are observable all through the glass base. Some of these appear to be tubes, sometimes truncated obliquely; others are polygonal or rounded. These are mixed up with numerous "belonites," very similar in appearance to those of pitchstone, and about the same size as those in a specimen from Ascension Island with which I compared them.

(4). *Specimen from Rathjordan* (Upper Trap-band, columnar).—





G.L. Griesbach

Mintern Bros imp

Microscopic Crystals Observed by Prof. Hull in the  
Trap-rocks of Limerick.

This specimen much resembles the last. The glass base contains belonites, and cavities; and along with well-defined brownish crystals of augite are numerous pseudomorphs after olivine, filled with the chloritic mineral which is so abundant in these rocks (figs. 3, 4 and 5).

(5). *Specimen from Ballybrood* (Upper Trap-band).—This is similar to Nos. 3 and 4. The glass base contains belonites and numerous elongated cells. The form of the crystals of augite are remarkably well defined, but the substance of the mineral itself is often replaced by chlorite and calcite (figs. 12, 13, 14 and 15). The crystals of magnetite often present well-defined forms, but I could observe none resembling those of olivine.

(6). *Specimen from Ballytrasna—Porphyritic* (Upper Trap-band).—I have two slices of this. The base is a glass with cells and belonites in places, much charged with magnetite grains and crystals. In this are imbedded well-formed augite crystals of a light-brown colour, with imbedded grains of magnetite, (fig. 2). One of these (a fragment) is a large hexagonal crystal filled with a colourless and structureless mineral, probably calcite. There are numerous large crystals and groups of banded felspar (fig. 1), with a very fine appearance under polarized light; the augite crystals—showing a fine play of golden bronze, and roseate colours on rotating the upper prism—are remarkably well formed; and on the whole this specimen is one of the best examples of the type structure of the melaphyres of the district. It bears a close resemblance to the rock from the "Lion's Haunch," Arthur's Seat, near Edinburgh, of which I have had an opportunity of examining a section, kindly lent to me by Mr. Allport, F. G. S. With the quarter-inch object-glass, well-defined cells were observed in the augite crystals.

(7). *Specimen from Carrigogunnel*.—This specimen comes from an outlying district, separated from the Trap-bands of several miles of limestone. Its position is about  $4\frac{1}{2}$  miles W. of Limerick, and it is supposed to be contemporaneous with the "Lower Trap-band." The trap itself is interposed between beds of ash.<sup>1</sup> The base, as seen with a high power (quarter-inch), consists of a highly crystalline triclinic felspar, containing ill-formed augite crystals, rounded or oval greenish grains (probably pseudomorphs after olivine), long prisms of triclinic felspar (probably Labradorite), and groups and grains of magnetite. The feldspathic base is throughout highly crystalline, and is seen (with the quarter-inch object-glass) to contain numerous cavities, sometimes elongated, at other times oval or round.

*Olivine* (?).—An oval-shaped large grain, filled with a nearly colourless material, but having numerous star-like radiating centres and

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<sup>1</sup> See Explanation to Sheet 143, p. 25.

curved lines in green, resembles one of the figures of olivine structure given in Dr. Zirkel's work on the structure of basalt.<sup>1</sup>

*Felspar crystals.*—The long prisms of triclinic felspar are very like those of the Antrim dolerites, which are known to be formed of Labradorite felspar.

(8). *Specimen from Knockes.*—Dark compact trap (outlying boss supposed to belong to the Lower Trap-band).—Colourless base with slender prisms of triclinic felspar; large quantities of magnetite in crystalline grains, a few crystals of augite, and numerous grains and patches of a greenish mineral. The augite grains are exceedingly minute and scarce.

*Olivine (?)*.—Some of the greenish grains when examined with the quarter-inch object glass show a radiating fibrous structure somewhat resembling that of one of the specimens of olivine figured by Dr. Zirkel; and on the whole, although the crystalline form of this mineral is often not at all, or only obscurely developed, I have little doubt that these grains are olivine, or its pseudomorphs.

(9). *Mottled dark purple amygdaloidal trap, Herbertstown* (top of Lower Trap-band).—Base a colourless glass, sometimes stained brown, containing small prisms of triclinic felspar, and containing cavities sometimes filled with a green structureless mineral (chlorite?), but generally with calcite.

The slice is not sufficiently thin, and is so much stained by oxide of iron, that other minerals are not discernible. With polarized light the banded structure and opalescence of the calcite, which fills the fissures and cavities, is remarkably well shown.

(10). *Specimen from Cahermurry.*—Glassy cellular base, amygdaloidal, tinged deep-green by chlorite (?), with some small prisms of triclinic felspar. Many of the cells are filled either with a green fibrous mineral (chlorite?) or calcite, or both. (Figs. 6, 7, 8). The dark base is due to abundance of magnetite and chlorite.

(11). *Specimen from Knockdirk* (an outlying mass, considered to be a "root" or "neck" of one of the old vents).—This rock, as Dr. Apjohn has observed, is different from the other Trap-rocks of the district. He says, "On this hill is a close-grained greenstone, which graduates into a clinkstone possessing sometimes an olive green, sometimes a red, but more usually a brownish tinge." The specimen in my possession from which the slice was taken is reddish in colour, and of a crystalline granular structure.

It consists of a colourless, or slightly stained feldspathic base, with crystals of orthoclase, and grains of silica. There are also a few crystalline grains of magnetite, and irregular patches of green chlorite.

<sup>1</sup> Untersuchungen über die Mikroskopische Zusammensetzung der Basaltgesteine (1870).

<sup>2</sup> *Supra cit.* p. 82.

*Silica.*—As in the case of granite, the silica forms a paste in which the felspar crystals, as well as some of magnetite, are imbedded, and it was clearly the last to consolidate. Small cavities and cells may also be observed with the quarter-inch object glass. Some of these are in the form of long tubes extending in various directions through the mineral.

*Felspar Crystals.*—These I assume to be orthoclase from their frequent rectangular form, and the absence of bands or fine lines characteristic of the triclinic feldspars. It was also to be expected that in a rock so highly silicated as this, orthoclase would be present. I could observe no augite crystals.

On the whole, it is clear from the composition and structure of this rock that it is altogether of a different species (or indeed genus) from the traps above described, and approaches more nearly to the composition of a trachyte, or clinkstone, than to that of a basalt or melaphyre. It is the only one in which silica appears as an essential constituent and in large proportions.

The points specially noticeable in reference to the above specimens, which may be regarded as fair representatives of the Limerick Carboniferous melaphyres, are the following :—

- 1st. The glassy felspathic base with cells and tubes.
- 2nd. The small quantity of augite, this mineral only occurring in the form of scattered crystals or grains.
- 3rd. The abundant infusion of chlorite, or more rarely epidote, not only filling in cavities and interstices between the crystals, but also replacing in many cases, the original minerals themselves (augite, olivine, etc.).
- 4th. The abundance of calcite, also due to percolation, and of secondary formation.

*Antrim Miocene Basalts.*—Considering that the rocks I have just described may be regarded as the more ancient equivalents of the Tertiary basaltic sheets, it may be interesting to compare their respective structures.

I have examined a considerable number of sliced specimens taken from various parts of the Antrim trap-area, and it is remarkable that they all present a nearly uniform structure, notwithstanding different degrees of crystallization. In this case the augite, instead of being imbedded in a crystalline form in a colourless glassy base, is itself the base, inclosing prisms of triclinic felspar, grains of magnetite, or titanoferrite, and sometimes olivine. Chlorite is also present, but not so frequently as in the Limerick melaphyres, and the whole rock is in a less altered state. Thus, if we compare the composition of the Limerick and Antrim traps, we would find that the relationship is somewhat as shown below :—

*Relative proportions of minerals in the Melaphyres of Limerick and the Basalts and Dolerites of Antrim, Down, etc.*

LIMERICK. Carboniferous.		ANTRIM. Tertiary.	
Base	{ Augite crystals.	Base.	{ Triclinic felspar.
Colourless glass, containing	{ Triclinic felspar, Magnetite.	Augite, containing	{ Titano-ferrite.
	{ Olivine (Pseudomorphs).		{ Olivine (sometimes).
	{ Calcite & chlorite (accessories).		{ Chlorite (sometimes).

It will be thus seen that the relations of the minerals are quite different in each case, and it seems probable that this is due to the greater abundance of augite in the Antrim traps:—so abundant as to have itself become the base. In the case of the Limerick melaphyres the mineral occurred in such small quantities that it crystallized out in individual crystals, bearing a small proportion to the whole mass of the rock. This points to essential differences in the two magmas, involving some interesting chemical inquiries.

The distinction here stated between the structure of the Carboniferous and Tertiary augitic rocks (melaphyres and basalts) is not admitted by Mr. Allport, with reference to similar rocks of England and Scotland. Mr. Allport's opportunities of investigation, however, have been much larger than my own, and the result he arrives at may be thus summed up in his own words:—

"I have abundant evidence that melaphyres of undoubted Carboniferous age, and basalts of Tertiary age, have not only the same mineral constitution, but also that both present the same structural varieties."<sup>1</sup> My observations tend rather to confirm the opinion of Mr. Forbes, as expressed in his paper "Researches in British Mineralogy."<sup>2</sup> And the glass base of the Limerick melaphyres is in keeping with the general character of the basaltic rocks as described by Dr. Zirkel.<sup>3</sup>

## EXPLANATION OF PLATE VII.

- FIG. 1.—Twin crystals of triclinic felspar, inclosing spangled greenish grains, probably of olivine. From Upper Trap-band, Ballytrasna.
- FIG. 2.—Augite crystal, inclosing magnetite grains. From Upper Trap-band, Ballytrasna.
- FIGS. 3, 4, 5.—Crystalline grains of olivine replaced by chlorite, and inclosing (No. 5) magnetite crystals. From Upper Trap-band, Rathjordan.
- FIGS. 6, 7, 8.—Cells in amygdaloid, filled with green chlorite (or epidote) and calcite. In No. 7 the green mineral has an excentric arrangement. The calcite is colourless, with a peculiar banded structure, and iridescent to pearly lustre. Cahermarry.
- FIG. 9.—Portion of glass base—magnified about 200 diameters—showing tubes, cells, and belonites, and inclosing crystals of magnetite. From Upper Trap-band Rathjordan.
- FIG. 10.—Twin crystals of hornblende, brownish colour, inclosing magnetite grains. Lower Trap-band, Roxborough.

<sup>1</sup> Geological Magazine, vol. viii., p. 449.

<sup>2</sup> Phil. Mag., vol. xxxiv., p. 336.

<sup>3</sup> *Sup. cit.*, p. 88.

FIG. 11.—Pseudomorphous crystal after hornblende, the substance of the mineral replaced by chlorite or epidote, and calcite. Roxborough.

FIGS. 12–18.—Forms of augite crystals, or pseudomorphs, mineral sometimes replaced by chlorite and calcite, as in Figs. 12, 13, 14, 15, and 16; from Ballybrood. FIG. 17 represents a crystal of augite from Upper Trap-band, Ballytrasna. Nos. 13 and 15 are twin crystals.

The figures have been sketched by the hand direct from the microscope by the author, from slices prepared by Mr. Jordan, of the Mining Record Office, London.

XXVII.—OBSERVATIONS ON THE MICROSCOPIC STRUCTURE OF IRISH GRANITES.\* (No. 1.) By Professor EDWARD HULL, M. A., F. R. S. (PLATE VII. *bis*.)

[Read 9th April, 1873.]

*Granite of Fərbogh. Galway Bay.*—I propose, as time and opportunity permit, to give the results of observations on the microscopic structure of Irish Granites, commencing with one from Galway.

This is a porphyritic granite from the great tract of granitic rocks which stretches westward from the town of Galway itself. It consists of a base of silica, dull waxy felspar, and dark-green mica in nearly equal proportions, in which are embedded pink or flesh-coloured crystals of orthoclase. These last are sometimes half an inch in length, and though generally occurring as individuals, are often present as twins. The granite is foliated, and probably of metamorphic origin.

*Silica.*—Silica occurs without crystalline form enveloping all the other minerals. It is structureless, but full of cells which are visible with a high power. With polarized light, and on rotating the upper prism, the silica presents the usual gorgeous play of colours; being broken up into distinct patches of irregular form, each refracting different prismatic colours. Some of the patches show round their edges parallel wavy bands of prismatic colours, marking out the individuality of the patches, and indicating the manner in which the particles consolidated in independent masses of various sizes—sometimes exceedingly small. The cellular structure of a portion of the silica is shown in Fig. 4. These cells are often so minute that three successive series are brought into the field upon changing the focus of the microscope by means of the mill-headed screw, with a magnifying power of 350 diams. Along with the cells are numerous long “belonites,” or “trichites,” sometimes perfectly straight, and stretching in all directions through the mass of the silica. With the 1-inch object glass these can be generally observed. but with the

\* Extracted from the Geological Magazine, vol. x., No. 5, May, 1873.

$\frac{1}{4}$ -inch and the No. 2 eye-piece, magnifying 350 diams., they are very well brought out, sometimes in extraordinary numbers. Even with this power their apparent thickness is not so great as that of the finest needle, with an apparent length from an inch downwards. In one or two instances they appear to be barbed, but this may be owing to the meeting of two trichites at a point: there are also examples of trichites slightly bent or curved. The general appearance of these in one part of the field is represented in Fig. 4. Sometimes the silica contains cells only without trichites.\* What the nature of these needle-like objects may be I have no means of judging from this slice.

Cavities are exceedingly numerous in the silica. Some of these resemble the forms described and figured by Mr. Sorby in his admirable and well-known paper "On the Microscopical Structure of Crystals."† They are of various shapes, inclosing the little globule of fluid which just comes into view with a magnifying power of 350 diameters; and must be less than  $\frac{1}{1000}$  of an inch in diameter. Others, however, are much larger, and sometimes do not appear to contain any bubble; and, as Mr. Sorby suggests, the fluid may have escaped. One of the fluid cavities is represented in Fig. 5, others in Fig. 4.

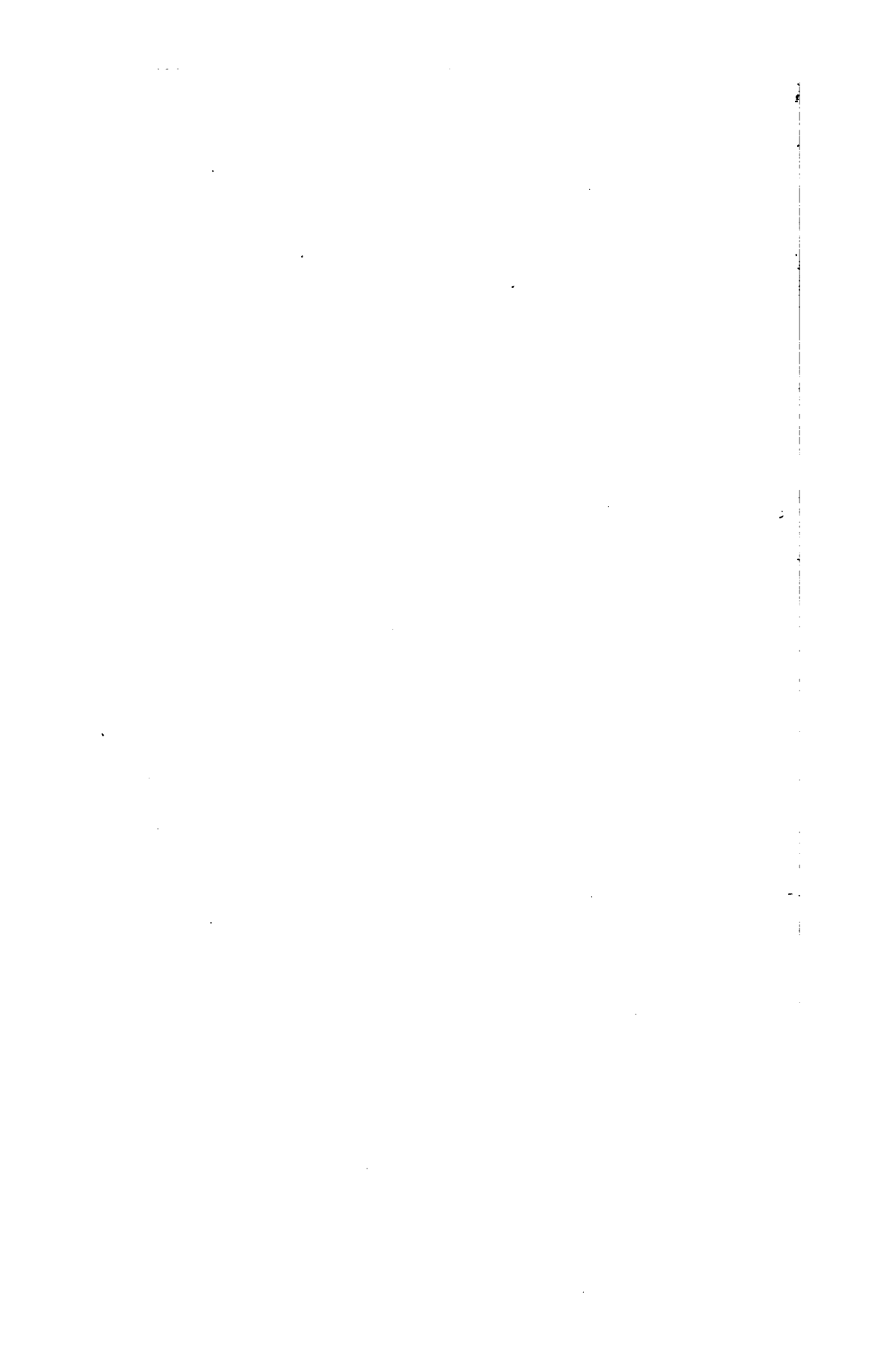
Stone cavities, or appearances which I take to be such as figured and described by Mr. Sorby, are also numerous in the silica. Along with the confused broken materials which they contain are also minute black specks. The form of these stone cavities is often very irregular and ill defined.

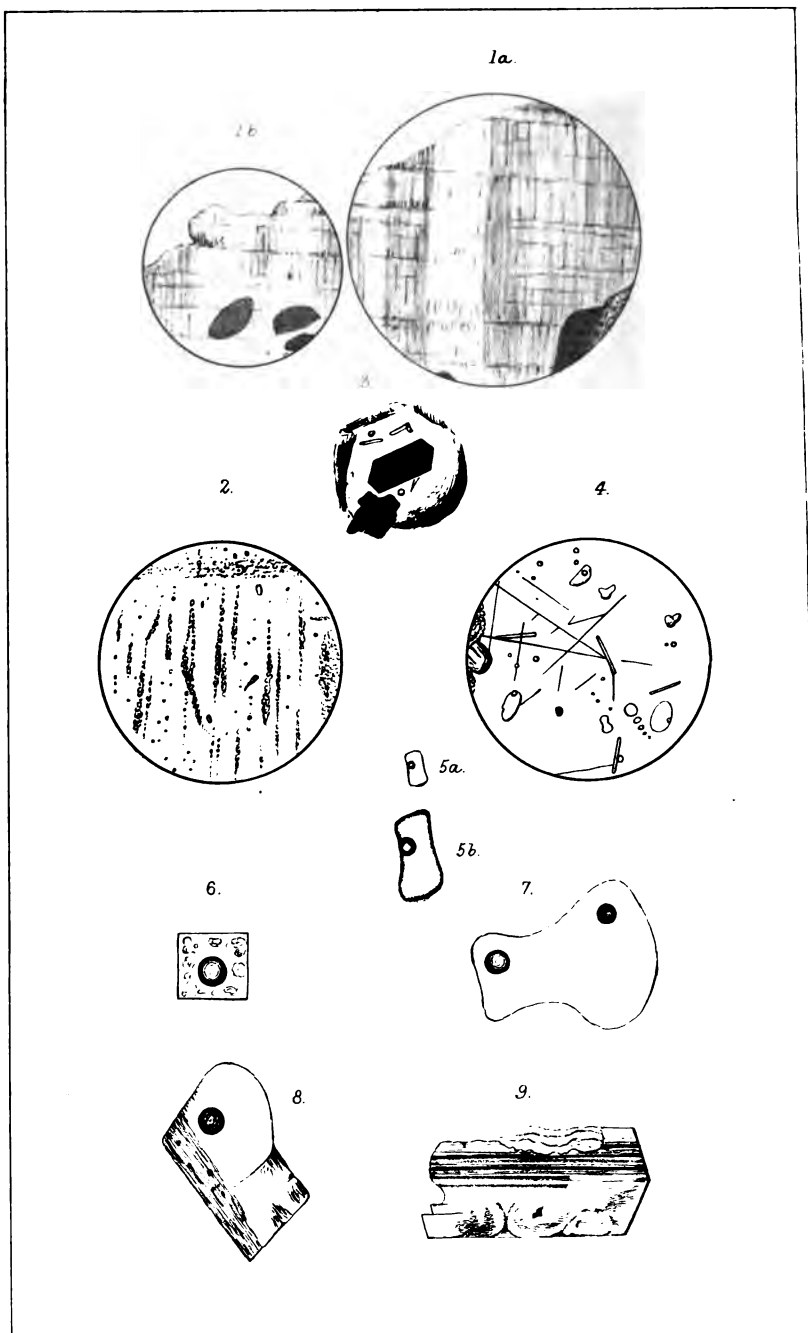
Occasionally perfect spheres occur, which may be assumed to be gas cavities. They are, however, rare; but one I have attempted to represent (Fig. 6), is associated with several others, and is of the apparent size represented, when magnified about 1000 diams. Figures 7 and 8 are similar spheres in the silica of a reddish porphyry from the Old Red Sandstone of Lesmahago, which are inserted for the sake of comparison. They are exceedingly beautiful objects under the microscope, the opaque walls shading off into the translucent centres through a series of delicately blended purple rings.

*Felspar* (Triclinic).—The dull waxy-looking felspar of the base is triclinic, and in all probability oligoclase. With polarized light the paralld-banded structure characteristic of triclinic felspar is apparent in the case of several small crystalline grains (see Fig. 9), but the bands of colour are less vivid than in the case of some albite felspars. I hope

\* I am uncertain whether to use the term "belonites," "trichites," or "nadelchen,"—terms used by Zirkel and Allport for somewhat similar objects in the base of some basalts. Apparently similar hair-like bodies from the "sanidinite" of Mont Dore are considered by Dr. A. v. Lasaulx to be hornblende. Poggen. *Annalen B.* 144, p. 156.

† *Quart. Jour. Geol. Soc., Lond., vol. xvi. p. 453.*





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To illustrate Prof. Hull's paper on the Microscopic structure  
of Irish Granites.

on a future occasion to compare the relative refractive powers of albite and oligoclase in granite.

*Orthoclase.*—This felspar predominates, not only in the larger individual flesh-coloured crystals, porphyritically developed, but in the base itself. In the case of the larger crystals, however, it presents a very remarkable appearance, especially when seen by polarized light, showing a *cross-banded* structure of a kind very dissimilar from the banded structure of the triclinic felspars (Fig. 1). This structure I have observed in thin sections of granite from other districts, such as Dublin and Wicklow; but not in the felspar of any other rock but granite; and my present impression is that the cross-banded structure is characteristic of granitic rocks. Dr. Zirkel has, I believe, observed a similar structure.

This structure differs from that of the triclinic felspars, in that the bands of colour are somewhat irregular, interrupted, and crossed by other bands perpendicular, or nearly so, to the former. On rotating the analyzer, the colours change through purple shading into yellow, grey, and blue shading into green. At first I was in doubt regarding the cause of this peculiar appearance; but with a high magnifying power all doubt vanished. It was then seen to be due to a cellular, or tubular, structure; the whole mass of the mineral being penetrated in two directions by a series of irregularly parallel tubes, or in reality planes of cells, tapering in both directions and appearing like strings of little beads hanging from invisible points. This structure is best seen by using the lower prism ("polarizer") only, and observing the section with the  $\frac{1}{4}$ -inch object-glass, when it will appear somewhat like that represented in Fig. 2. Some of the lines of cells are straight, others bent a little, while the intervening portions of the mineral are perforated by very minute solitary cells. A portion of one of the *longitudinal* bands of cells is represented in the upper part of the figure. These are visible with the  $\frac{1}{4}$ -inch power in special parts of the thin slice, and though not so numerous as the *transverse* bands, are more continuous. They are also lines or bands of weakness; for in the slice, the margin of which passes across one of those cross-banded felspar crystals, there is always a little notch at the point where the band meets the edge. In speaking of this cross-banded felspar as "orthoclase," I am assuming that the large crystals in the slice belong to the large flesh coloured crystals in the rock itself, which are known, by the determination of Dr. Haughton, F. R. S., to be orthoclase. Of this I have no doubt; and even if the evidence was less positive under this head, I should have concluded the mineral to be orthoclase from the absence of the fine parallel lines and bands of colour when viewed with polarized light. As regards the arrangement of the longer (or horizontal) bands of cells, my friend Dr. Emerson Reynolds, on viewing the slice, suggested to me that they must coincide with the planes of cleavage of the crystal, as it would be naturally along such

planes that the cells, whether filled originally by gas or steam, would arrange themselves. The parallelism of these bands confirms this view.

*Mica.*—The foliated structure of the granite is well exemplified by the arrangement of the mica in the slice. Besides scattered flakes imbedded both in the silica and felspar, there are three irregularly parallel bands crossing the section transversely, and composed of numerous sets of twisted flakes, sometimes rich brown or bronze in colour, sometimes almost colourless. As usual, they are all deeply scarred, and are sometimes quite opaque, or slightly translucent. One minute crystal, showing the hexagonal form, is inclosed in a cavity in felspar (see Fig. 3). Some of the black specks seen in the mica I suspect to be magnetite, representing the excess of iron over that which has entered into the composition of the mica itself. The forms, however, are not so satisfactory as in one or two other instances in which I have observed grains of magnetite in the mica of granite, as, for instance, in the granite of Killiney Hill. The mica in the section seldom shows well-defined crystalline forms; and along its margin is entangled with the other minerals, often in so ill-defined a manner as to suggest the idea of a mineral in process of formation. May not this be an appearance due to the metamorphic origin of this granite itself? I am still, however, in doubt, whether the rich bronze-coloured mica is of a different species from the colourless, but equally twisted and scarred variety, seen under the microscope.

#### EXPLANATION OF PLATE VII. *bis*.

- FIG. 1, *a, b*.—Portions of large felspar crystal, showing cross-banded structure with polarized light, mica-flakes in lower part of the field; magnified 25 diameters.
- FIG. 2.—Portion of No. 1, magnified 200 diameters, showing cellular structure in both directions; also numerous little cells in the spaces intervening between the lines of cells.
- FIG. 3.—Cavity in felspar, with a well-formed crystal of mica (?) and a mica-flake, together with little transparent prisms and grains; magnified 350 diameters.
- FIG. 4.—Group of fluid cavities, minute prismatic crystals, and trichites in silica; magnified 200 diameters.
- FIG. 5 (*a*).—Fluid cavity in silica; magnified 350 diameters.
- (*b*).—The same enlarged; the fluid bubble resting on one side of the cavity.
- FIG. 6.—A spherular gas-cell in silica; magnified about 1000 diameters.
- FIG. 7.—Spherular cells in silica, from quartz-porphry of Lesmahago, Scotland; magnified 55 diameters.
- FIG. 8.—Part of a mica-crystal, replaced by silica, and containing a spherular gas-cell; Lesmahago, magnified 55 diameters.
- FIG. 9.—Crystal of triclinic felspar, probably oligoclase; magnified 25 diameters.

The slices were prepared by Mr. J. B. Jordan, of the Mining Record Office.

XXVIII.—THE COAL-FIELDS OF CENTRAL INDIA, FROM THE REPORTS OF  
THE GEOLOGICAL SURVEY OF INDIA AND OTHER OFFICIAL SOURCES.  
By MEADOWS TAYLOR, V. P. R. G. S. I.

[Read March 12, 1873.]

I HAVE been induced to draw up this paper from various official sources, on account of the great interest which belongs to the subject in connexion with the maintenance of several of the main lines of railway in India, the provision to them of apparently inexhaustible resources of fair working fuel, and their probable future extension; and as the sources from which the particulars are derived are not generally known to the public, it may be useful, as well as interesting, to sketch the various operations that are at present employed both in mining for coal in the localities where it has been discovered, and in continued scientific exploration of tracts of country, where, from the geology of their formations, more coal beds may, it is hoped, be gradually discovered. I need hardly state that it is to the skill, patient labour, and perseverance of the officers of the Geological Survey of India, several of whom are Irishmen, that the recent most valuable discoveries have been effected. Of these officers, Dr. Oldham, Mr. Blanford, and others are well known to the members of this Society; and while we rejoice at their success, I am well assured that they receive our hearty congratulations on their efforts.

When the establishment of railways for India was first discussed, the question of supplies of fuel in adequate quantities formed a very important and prominent section of inquiry and discussion; and I believe that there were many, well-wishers in general to the great measure, who, nevertheless, viewed with the utmost apprehension the outlay of an enormous amount of national capital in undertakings, the prosecution of which depended upon supplies of fuel from England, and the greatly enhanced cost at which alone it could be supplied to India. It was also urged, and with truth, that war with any European power might at any time hinder the supply to an alarming extent: or so increase the cost of transit as to make the employment of English coal prohibitive of profitable return. In India itself, only one supply of coal, that of Bengal (Ranigunje) was then known to exist, and this to be inferior to English for steam purposes. It might indeed serve the purposes of the eastern railways to some extent; but its transit to the western and southern lines seemed well-nigh impossible. India is not in general a well wooded country, and supplies of wood even from the forests of Central India could only be of limited extent and proportional benefit. Other fuel there was none, except dried cakes of cow dung, which burn like turf, and are used by the people of the North-west provinces, the Punjab, the Deccan, and Southern India, wherever the country has been denuded of wood, under advanced cultivation.

The question of enhanced price of coal which has recently arisen in England was not then discussed at all, as well as I can remember, in India; nor even its bare probability argued; but the necessity of the employment of English coal, no other alternative being apparent, necessarily confined the projects for railways to the most direct lines suitable for the public service, and allowed of no consideration of branch lines and feeders. Such was the condition of the great fuel question in India till the discovery of the coal fields I am about to describe, which, there can be little question, will eventually render India, for the most part, independent of England in periods of extravagant cost of coal, or possibly interrupted supply; and will enable other great lines than those which exist at present to be laid down from time to time with the absolute security of fair working coal being found on or near them.

I will now proceed to describe the fields themselves which exist in Central India only. I do not propose to describe those of Ranigunje in Bengal on the River Damooda, because their discovery is of much older date, and details of them are comparatively well known to those interested in Indian coal measures.

*Tawa Valley, Baitool district, central provinces.*—This coal field was first examined and reported upon by Mr. J. G. Medlicott of the Indian Geological Survey in connexion with his examination of the central portion of the Nerbudda district, and whose report will be found in Vol. II. of the Memoirs of the Geological Survey, and secondly by Mr. W. T. Blanford, April, 1866, *vide* Records of the Geological Survey of India, Vol. I., Part I. The position of this field, lying, or some portion of it, within twelve miles of the G. I. P. Railway, near Hooshungabad, rendered its thorough exploration highly necessary with a view to utilizing the coal as a feeder to the railway supplies at a point nearly equidistant between its extremities. Mr. Medlicott's examination appears to have been made in 1856, when he estimated the seams at "Rawundeo" to be 21·2 inches thick in eight outcrops; the other seams (six in number) of a smaller amount, varying from three inches to three feet in thickness, and his opinion was not favourable in regard to mining operations.

Mr. Blanford confirms the unfavourable opinion of his predecessor. "I doubt," he writes, "if a single seam is known to occur in the valley which could be mined to any depth with profit under existing circumstances, and with one possible but very dubious exception, I am decidedly of opinion that no seam could be worked under any possible circumstances. This possible exception is the Rawundeo section, to which Mr. Medlicott particularly called attention; but there are some peculiarities connected with the seams there found, which make me think their availability for mining purposes doubtful."

Mr. Blanford examined five localities in the valley in the courses of the Tawa and Machna rivers, which are tributaries of the Nerbudda. Of these, the only one which gave good promise is that at Rawundeo

on the Tawa. Here eleven outcrops of coal were counted; some of the seams are four feet thick, and the coal is of excellent quality; but the seams appear very variable in all the localities; thinning out to a few inches in thickness in a short distance. The roofs of the seams are generally coarse sandstone, though some are associated with flags and shales, that of the Rawundeo seam being flag.

The extent of this coal-field I do not find mentioned; but Mr. Blanford considers it probable that coal might be cut at Kesla or Bagra, about ten miles lower down, that is, north of Rawundeo, and nearer the railway. No subsequent examination however appears to have taken place; nor have any borings, in any part of the field, as indicated by the outcrops in the beds of the Tawa and Machna been attempted, and the estimates already made are solely derived from the outcrops. Mr. Blanford, however, considers that as the position of the probable seams at Kesla is higher than the others, the result in reference to the seams of coal in the great Raneegunge field might be more favourable. "I am inclined to believe," he writes, "that the beds of the Tawa valley resemble those of the lower, or 'Barakar,' series of the Raneegunje field in the peculiarities of the coal seams, as they certainly do in their position at the base of the coal measures."

However valuable then, in regard to position near the course of the railway, and in regard to the quality of the coal, even of the outcrops, there does not appear to be any chance at present of the seams of the Tawa valley being worked, though further exploration may happily render them of as much notice as the Mohpani fields, which, from the locality, appears to belong to the same formation.

*The Mohpani Fields.*—These lie about eighty-four miles north-east of the Tawa fields, in a direct line, at the foot of the same range which forms the southern basin of the Nerbudda river between Hooshungabad and Jubbulpore. They are bounded by the River Doodhy on the west, and the Sita-riva river on the east, both streams having their rise to the south in the plateaux of Deogurh; and intersecting the basin plain of Nursingpore, fall into the Nerbudda river. Mohpani appears to be a small village or town near the Sita-riva river, where it debouches into the plain from the hills which lie to the south, and which ascend gradually to the high plateaux of Deogurh, Gondwana and Baitool. The geological features of the districts consist of trap in the higher portions underlaid by sandstone, in which the coal deposits are found. The valleys of the rivers have resulted from denudation till the sandstone was reached in many places, showing in the beds of the streams outcrops of coals.

Mr. Medlicott's report on these fields was made in 1870, and is, perhaps, the latest authority on the subject. It is given in length in the Records of the Geological Survey of India, No. 3, of that year, and is of the highest interest throughout; but it is too long for extract entire, and I will endeavour to give an abstract of it by quotation of the passages which more particularly bear upon the coal deposit.

The exact locality of the Mohpani field is found from the Gurrawara station of the S. I. P. Railway, which is situated about twelve miles north of the coal-field.

"With the exceptions of Mohpani," writes Mr. Medlicott, "and the less known case near Lohartalai, all the observed coal localities occur close to the south border of the basin of stratified rocks, far from the Nerbudda valley of the south tributaries of the upper Tawa, and in the valley of the Penah river.

"The wide separation by intervening barren (coal-less) rocks in the several localities where coal appears at the surface within the large area, hitherto generally referred to as the Nerbudda coal basin, necessitates the recognition of as many distinct coal fields. Of these, the Mohpani field is at present the most important by far, on account of its superior position, and because the value of the seams has been proved by actual mining. It is traversed by the Sita-riva river, in which the entire section is exposed in a length of about a mile and a half. On the south the measures are buried under lofty hills of younger rocks. On the east from the sharp bend of the river the field is rapidly cut off by an overlap of the same strata. To the west the extent of the field is very obscure and doubtful; for some miles from the Sita-riva the ground is very much covered, the talus from the ridge to the south of the measures being confluent with the superficial deposits of the plains, so that only a few and uncertain outcrops can be seen. A little further west, however, in the Dharajhir, a complete section is obtained up to the metamorphic rocks at the edge of the basin." . . . Thus for a description of the field and its extent, there is little more data than is available from the natural outcrops. The extent of this information, and the field as at present known, may be judged from the statement that one square mile would very nearly include all the localities where coal is visible, and fully half of this square mile is occupied by rocks below the coal measures. It may be confidently expected that the coal exists, and can be followed over a much larger area; but it needs no more at present to show how impossible it would be to arrive at a correct estimate of the extent or value of the field until further trials have been made.

*Formations.*—There are three formations to be considered. The Mahadeva series—the Barakar group, or the coal measures—and the Talchir group, besides Trap-rock, metamorphic rocks, and the superficial clays and gravels, or wash-drift.

*Mahadeva.*—The Mahadeva series is of great thickness, and comprises a great variety of rocks; but, as here exposed, at and near their contact with the coal measures, maintains very constant character, being formed of massive coarse conglomerates, sandy, earthy, and generally more or less rusty. With these are capriciously but freely associated, beds of deep red clay, sometimes mottled and calcareous, or even with nodular layer of limestone. On the tops of the hills, and generally at a distance from the edge of the basin, the Mahadeva formation is

largely composed of sandstones above, associated with earthy bed below.

It is important to notice here the coal that occurs in this formation. Its characters are everywhere the same—a bright jetty lignite coal disseminated in threads more or less abundantly in thick shale, and sandstone. The proportion of coal is exceedingly variable, and, except in rare cases, altogether too small for use.

This coal has been cut and used in many somewhat widely divergent localities, with the same invariable result. The coal itself is quite unlike the Damuda Barakar coal.

*Barakar Group.*—The Barakar group is not more than 500 to 600 feet thick; composed of strong beds of gray and white felspathic sandstone, alternating near the top with carbonaceous shales and coal beds. Wherever the section is exposed in the neighbourhood of the Sita-riva these beds are found close beneath the bottom red clays or conglomerates of the Mahadevas.

*Talchir Group.*—The Talchir group is typically characterised by beds of fine greenish silt or silicious clay and sandstones, in either, or both of which, pebbles and boulders often of large size are thinly scattered. The fine earthy sandstones pass up by imperceptible gradation into the Barakar rock, so that the boundary between them in the absence of characteristic fossils, must often be arbitrarily assigned. These rocks occupy a large space between the north and south outcrops of the coal measures in the Sita river.

*Traprock.*—Traprock forms an important consideration in the valuation of this field. It occurs both in dykes and in outlying masses; but is all of the same description—a dense basaltic rock; and, as far as present evidence goes, it may be all of the same age.

The change in the quality of the coal is quite in accordance with the crushed condition of the strata. The coal from the vertical seams is friable and dusty, and burns without smoke, all the bituminous matter having apparently been extracted from it. It is, consequently, slow to ignite, but has strong heating power. The coal, in its normal state, at the Nerbudda Company's mines, has the usual composition of Indian coals. The subjoined analyses, made by Mr. Tween, exhibit the change:—

		Carbon.	Volatile	Ash.
1.	Nerbudda Company, top seam, . . . . .	55·8	32·6	11·6
2.	Do. do. 2 feet band of spurious Cannel, . . . . .	33·1	24·6	42·8
3.	Do. do. main seam, . . . . .	50·4	39·0	10·6
4.	Do. do. do. . . . .	51·0	33·4	14·7
5.	Sita Riva Company, top seam, . . . . .	67·9	8·8	23·8
6.	Do. do. main seam, . . . . .	59·0	15·0	26·0
7.	Do. do. do. . . . .	70·7	9·5	19·8

Small as are the workings (the most extensive being about 400 feet long by 150 broad), they are on all sides stopped out against faults. It is true that none of these seem to have any great throw, but their frequency, and the crushing of the coal that attends them, is a serious obstacle and loss.

*Rough estimate of the field as far as proved.*—Any estimate of the available coal supply in this region must be affected by two considerations that do not present themselves in other Indian coalfields; these are the frequent high dip of the seam, and the fact that, almost at all points, thick overlying rocks rise into hills of considerable height close over the out-crop of the coal. Both these conditions will involve deeper mining than has yet been attempted in India; in many places they would restrict the mining to what can be obtained at or near the out-crops; and, applying this rule to the known length of out-crop in the Mohpani neighbourhood, we arrive at an approximate estimate of the coal from existing data. It may be said that there are about two miles of known out-crop, the coal being obscurely visible at the surface at several spots along the curved line between the two collieries, *but its thickness in that position has not been tried*. Assuming it to maintain a mean thickness of workable coal between the aggregates at the two collieries, say 25 feet, at the rate of 1000 tons per foot of thickness per acre, per seam, we should have 400,000 tons for every 66 feet down the seam for the whole length of two miles. As in many places the seam may be followed for many hundred feet, it is apparent that, without any very unwarrantable assumption, we may count upon a large supply of coal for many years to come."

In regard to the probable further extension of this coalfield, Mr. Medlicott's observations are too detailed and too long to enable me to quote them here; but it may be inferred from the geological structure of the basin, and the various out-crops in its different localities, corresponding with those of the Tawa Valley, that it is probably of very great extent, eastwards, westwards on the flat ground, and southwards and westwards along the base of the ridge. These, however, would not be intelligible without a map of the whole of the great basin, which is under preparation by the Topographical Survey.

At the period of this report, the branch line to connect the collieries with the railway had not been constructed, and questions were still raised as to the quality of the coal, upon which all reasonable doubt had long since been settled; for it may be safely asserted, writes Mr. Medlicott, that a large portion of the coal now consumed on the East Indian Railway is no better than the Mohpani coal. For the Jubbulpore line, and even as far as the Nainè junction, the Mohpani coal could undersell the Bengal coal, and a considerable saving be made in the railway expenditure. It may be hoped, therefore, the advantages of the presence of a coal supply in the centre of the line being so obvious, that the present hindrances to the use of the Mohpani coal may be overcome.

3. *Coal-beds at Kórba, in the Chutteesgurh Province.*—Note by Mr. W. T. Blanford, F. G. S.: "The coal-bearing, Damuda beds of Kórba, extend for about forty miles to the eastwards, as far as Rakkub in Oodeypoor; they also extend far to the south-east towards Gungpoor, and to the northwards towards Sirguja; and, in all probability, are continuous, or nearly so, with the deposits of the same nature known to occur in these districts."

Seams were observed in several places in the beds of rivers and watercourses, varying from three feet to one at the village of Tendamuni, which is twenty feet in thickness. Mr. Blanford also states that the officers of the Topographical Survey employed to the north of Korba and Oodipoor, have observed seams of coal in various directions, and it also occurs at a place northwest of Jushpoornuggur. All these indications would lead to a presumption that a very large, and, probably, connected coalfield exists in this locality. But Mr. Blanford being on his way to other duty could not remain to examine the whole minutely, and its survey was necessarily delayed. The distance of the locality, however, from any railway, renders this field of comparatively little use for the present.

Mr. Blanford's first note is dated 31st May, 1870. I find a second report of Mr. Blanford's dated the 18th April, 1870, in Vol. III. of the "Records of the Geological Survey." He had been able to revisit the Kórba field, and to make a more detailed and, to all appearance, a very encouraging report of the locality.

"The lower outcrop," he writes, "which is about half a mile below the village of Kórba, is best suited for examination, as both the top and bottom of the seam are exposed. The seam is remarkably thick, but owing to the mode of occurrence, it is impossible to measure it exactly. The dip varies in inclination from  $13^{\circ}$  to about  $18^{\circ}$ , and in direction from N.  $30^{\circ}$  E. at the northern extremity of the section to N.  $16^{\circ}$  E. at the southern end. The horizontal breadth of the outcrop, at right angles to the strike, is 350 feet, and taking the average dip at  $15^{\circ}$ , the corresponding thickness is 90 feet. This I believe is rather below the truth than in excess of it. Both above and below the coal, massive felspathic sandstones occur. Below the seam but a small thickness of these rocks is exposed; but above it, at least 400 or 500 feet, are seen in the river.

The section of the seam thus ascertained, is the following :—

Sandstone.					Feet. Inches.	
Shale, ... ..	...	...	...	...	1	0
Coal of fair quality, ... ..	...	...	...	...	1	0
Inferior coal, ... ..	...	...	...	...	1	0
Shale and ditto, ... ..	...	...	...	...	3	3
Good coal, ... ..	...	...	...	...	3	9 <i>a</i>
<i>Carried forward,</i>					10	0

Sandstone.	<i>Brought forward,</i>			Feet. 10	Inches. 0
Good coal, ... ..	...	...	...	6	0 <i>b</i>
Shale and coal, ... ..	...	...	...	1	0
Good coal, ... ..	...	...	...	3	0
Shale with bands of coal, ... ..	...	...	...	3	6
Good coal, ... ..	...	...	...	4	0 <i>d</i>
Coal and shale, ... ..	...	...	...	2	0
Shale with bands of coal, ... ..	...	...	...	2	0
Coal of fair quality, ... ..	...	...	...	1	6
Inferior coal, ... ..	...	...	...	0	6
Good coal, ... ..	...	...	...	5	6 <i>e</i>
Shale, ... ..	...	...	...	0	6
Coal, ... ..	...	...	...	0	3
Shale, ... ..	...	...	...	2	0
Coal, ... ..	...	...	...	1	0
Shale and inferior coal, ..	...	...	...	2	0
Good coal, ... ..	...	...	...	4	0 <i>f</i>
Shale with bands of coal, ... ..	...	...	...	3	0
Shale and coal, good in part, ... ..	...	...	...	3	0
Coal, generally good, ... ..	...	...	...	3	0
Shale, ... ..	...	...	...	1	0
Good coal, ... ..	...	...	...	1	0
Not examined, about, ... ..	...	...	...	3	0
Shale, ... ..	...	...	...	1	0
Good coal, ... ..	...	...	...	4	6 <i>g</i>
Not examined, ... ..	...	...	...	4	0
Shale, ... ..	...	...	...	4	0
Good coal with near two third-bands of shale, ... ..	...	...	...	6	8 <i>i</i>
Not examined, ..	...	...	...	3	0
Shale, ... ..	...	...	...	0	4
Good coal, ... ..	...	...	...	2	8 <i>j</i>
				89	0
Sandy shale, ... ..	...	...	...		
Sandstone, ... ..	...	...	...		

The above section shows a minimum section of 50 feet of fair coal. The proportion probably nearer two-thirds of the seam. The best bands appear those marked *b*, *g*, and *h*. Portions of those appeared to me equal in quality to any coal found in Ranigunje field. There is some iron pyrites here and there, but not throughout. The coal ignites readily, and burns with rather more flame than is usual in Indian coal obtained from the surface."

The second outcrop of coal occurs about 300 yards higher up the

river, and close to the same (right) bank. It is distinctly seen to be faulted against the sandstones which overlie the coal exposed at the southern outcrop. About 50 feet of coal are exposed, neither the top nor the bottom of the seam being visible.

The probable extent of seam is very large. East and west the coal-bearing beds extends to a great distance, and to the north-east they are apparently continuous with those forming the hills of Churi and Sutringi, and these are probably part of one large field which has been found by Mr. Medlicott to extend beyond Sirguja. My conclusions are briefly that both the quality and mode of occurrence are favourable. In thickness, in quality, and in the proportion of good coal to inferior coal and shale, this seam surpasses that near Chanda. The question of the extent over which it extends must be ascertained by boring.

The maximum of carbon by assay in this coal is,	...	60·5.
The minimum,	... ..	32·8.
Average,	... ..	46·6.

4. *The Chanda Coal-fields.*—This field lies near the town or city of Chanda, the southernmost district of the province of Nagpore, situated nearly due south from Nagpore, and lying along the left bank of the Wurdha river. The existence of coal had been known for some years, on reports by Major Lucie Smith, of outcrops in the bed of the river in various places; but no scientific exploration of the field had been made till 1867, when it was reported on very minutely by Mr. Blanford, whose report appears in the "Records of the Geological Survey" of that year.

In "Grant's Gazetteer" of the central provinces, I find among the geological descriptions of Chanda by Major George Lucie Smith, Deputy Commissioner of the provinces, the following passage in regard to the Damuda or coal-bearing sandstones :—" West of the Wain Gungah river, sandstones of the Damuda or true coal-bearing series of India, intermixed with those of other series, form a belt along the Wurdha, fairly parallel with its course, from a little above the village of Ekóna to the head of the third barrier of the Godavery Navigation Scheme, below Kirmiri. This tract is 75 miles long, and varies in breadth from 8 to 22 miles, comprising an area of about 1000 square miles. Seven seams of coal have already been discovered, one of which is 33 feet thick."

It is not necessary to follow the particulars of Mr. Blanford's first report; but he recommended boring trials in various localities, as a better test of the actual working value of the several seams, than out-cropping could possibly be, and this was carried out under the superintendence of Mr. Fryor, of whose proceedings a report is given by Dr. Oldham in Vol. II., part 4, of the "Records of the Geological Survey."

The first three borings were comparatively unsuccessful, two of them showing no coal whatever, the third 242 feet in depth, only one seam of 2 feet in thickness, and the Talchir series having been reached, the whole was abandoned. Several other unsuccessful borings ensued in different places, till the rods were put down near the village of Ghugus, about 330 yards from the bank of the Wurdha, above any flood mark. The bore hole was 121' 1" in depth, and gave the following result :—

Feet.	Inches.	
3	0	... Surface clay.
3	0	... Red moorum.
40	0	.. Variegated sandstone.
8	0	... White ditto.
6	0	... Green clay.
10	0	... Dark brown clay.
2	0	... Black shale.
3	0	... Coal.
3	0	... Dark sandy shale.
3	0	... Coal.
3	0	.. Blue shale.
12	0	.. Coal.
4	0	... Ditto, with iron pyrites.
5	0	... Coal.
0	6	... Shale.
11	6	... Coal.
<hr/>		
121	6	

The total of these seams is 38' 6". At this boring a pit was sunk, which it may be remembered was visited by the late Lord Mayo in his tour through Nagpore and Berar in 1871.

The first trial of the Ghugus coal on the G. I. P. Railway was not encouraging. The locomotive superintendent reported on the 16th of April that the coal was not suitable for locomotive purposes, being very dirty. "We could not get a welding heat with the coal, although it contains great quantities of gas." But a further trial was soon obtained, which, with a proper selection of coal, proved much more favourable. With Chanda (Ghugus) coal, steam was got up in 1 hour and 25 minutes, with a consumption of 36 lbs.; the weather being wet, a strong breeze blowing, and rain falling at the time. The coal burnt clear, freely, and *very clean*, leaving a small residue of grey ash, without clinkers, and evaporated on the average 4 lbs. of water per 1 lb. of coal consumed. With English coal, steam was raised in 1 hour and 25 minutes, with a consumption of 28 lbs., the coal being drier, but deteriorated from exposure, and small; the evaporation was at the rate of 6·5 lbs. of water per 1 lb. of coal. The Chanda coal is specially noted as burning clean.

The trial on the East Indian Railway was the only one in which the Chanda coal was compared with other Indian coal. The Locomotive superintendent reports that the consumption of Chanda coal on two trials was  $88\frac{3}{4}$  cwts., and 85 cwts. per 100 miles, against 67 cwts. of Ranigunge coal, for the same distance.

These trials show the "duty" of the coal, as compared with English coal, small and deteriorated by exposure, to be as 4 : 6·5, or 61 per cent., or in other words it is by two-fifths worse.

As compared with Ranigunge coal its duty was as 67 to 87, or 77 per cent., or nearly  $\frac{1}{4}$  worse. The coal, however, did the work required of it, and in a satisfactory manner.

The general average of the assay of the Wurdha Ghugus coal, at Calcutta is on thirty-one specimens—

Carbon,	...	...	...	44·51
Volatile,	...	...	...	35·84
Ash,	...	...	...	20·15
and of thirty specimens of Ranigunge coal—				
Carbon,	...	...	...	50·9
Volatile,	...	...	...	34·6
Ash,	...	...	...	14·5

that is, the Ghugus average coal is 6·39 per cent. inferior to the average of Ranigunge coal as to the main heating power, and it is also 6 per cent. worse than the same, as to the amount of useless matter. On viewing it another way, it may be said, that out of the 31 odd feet of coal, there are 28 which contain less carbon than the average of 30 Ranigunge coals, good and bad, and only three which contain more, while there are 23 which contain more ash than the same average, and only 8 which contain less.

These results appear unquestionable, so far as the coals yet obtained is concerned. That this coal will, at the same time, prove highly useful cannot for a moment be questioned, and we must only continue to seek for better.

In Volume III. of the Geological Survey Records, 1870, I find another long and detailed report from Dr. Oldham. Further explanations and borings had taken place, some of the latter being entirely unsuccessful, having been made outside the limits of the true Damuda series of coal measures. They were useful, however, to some extent developing the limit of the Chanda coal field. In one instance, however, near the village of Majri, coal was found at 75 feet below the surface, and gave the result of dark shale a little coal 0'·2". Coal 51'·8". Not all fine coal, but split up into beds of varying qualities. In another place 41 feet of coal was cut through in a total depth of 128 feet. These trials enabled Mr. Oldham to make an approximate estimate of the contents of the Chanda coal-fields as distinct from that of Berar lying across the Wurdha to the westward, and the result I give in his own words as follows :—

"Passing into Chanda (from Berar), we have equally an area of about one and-a-half square miles near Ghugus, making the same allowance as before for disturbed ground; and an area of about five square miles in the north of the field. And as the beds of coal are precisely the same, we take here the same estimate of thickness, viz. 20 feet. And proceeding on the same data, we will have, therefore, in Chandah,  $600,000 \times 6.5 \times 20 = 70$  millions of tons. This latter result fully bears out what was stated months since, that there was a very much larger amount of coal available in the assigned districts of Berar, than in the Chanda in the vicinity of the Wurdha."

*Coal-fields of Eastern Berar, Hyderabad Assigned Districts.*—

It was evident to the first explorers of the Chanda coal field, that as the coal out-crop in the bed of the River Wurdha crossed the river to right or western bank, it must either lead to deposits of coal similar to those on the left bank, or mark the possibly gradual thinning out of the seams, and their final limits, or that even larger deposits of coal than those cut into at Ghugus and elsewhere would be found. This was the scientific deduction both by Dr. Oldham and Mr. Blanford; and as the necessary borings were almost immediately begun, the uncertainty was speedily and most satisfactorily dispelled by the splendid result that has followed those operations. Not only was coal found wherever expected, but of a thickness and quality exceeding that of the Chanda or left bank series, as the official data I shall proceed to quote will prove. The result of the scientific explorations will, no doubt be given by Dr. Oldham in a future number of the Records of the Geological Survey; but for the present the Administration Report of Mr. C. B. Saunders, Resident at Hyderabad, under whom the administration of Berar is conducted, is the only authority I can quote.

Extract from Administration Report, Hyderabad Assigned Districts, by C. B. Saunders, Esq., C. B. Resident at Hyderabad, 1869-70.

Par. 308. "From certain important discoveries which have been made during the past year, there seems no longer any reason to doubt that the mineral resources of the assigned districts may truly be described as immense. That portions of these districts contained valuable coal and iron deposits was brought to notice some years ago; and in 1866, the Government of India sanctioned further researches being made in the Woon district. Early in 1867, a large quantity of surface coal was procured from Kumbharee in Woon, on the bank of the River Wurdha, and sent to the great Indian Peninsular Railway Company for experiment. This coal had been picked up from the surface, and, as might have been expected, proved of an inferior description; exposure to the weather having seriously affected its quality. The results obtained were, however, thought sufficiently encouraging to indicate the desirability of further explorations being made; and in 1869, the Geological Survey Department of the Government of India entered upon a detailed and systematic examination of the whole district. The explora-

tions were carried on during the cold season of 1869-70, under the immediate superintendence of Mr. Hughes, assistant in the Geological Survey, and with more satisfactory results than could have been hoped for. It now appears from the researches made that, though the Chandah coal-fields on the eastern side of the Wurdha were first taken up, and have thus attained, as it were, an established name, yet the great mass of coal, or five-sixths of the whole, lies to the west of that river, and within the confines of Berar.

309. The exploration of the two districts was carried on simultaneously, and the following information has been recorded from notes kindly furnished by Mr. Hughes:—

"The total area of the fields exceed one thousand square miles, of which only about 560 square miles have been carefully surveyed. The fields lie on both sides of the Wurdha, and the most appropriate name for the whole is, doubtless, that which has been adopted by the Geological department, namely, the Wurdha Coal-fields. Full particulars of the survey will very soon be published in the Official Record of the Geological Survey of India, but the results of researches in Berar, as far as have been ascertained, may be summarized as follows:—

"The series that enter into the Geological construction of the whole area are,

1. Vindhyan,	.	.	.	.	6	} <i>vide</i> Geological Map.
2. Talchir,	.	.	.	.	5	
3. Damuda,	.	.	.	.	4	
4. Kamthi,	.	.	.	.	3	
5. Trappean,	.	.	.	.	2	
6. Laterite,	.	.	.	.	1	

"The Damudas are represented only by one lithologically recognizable Bengal group, namely, the Barákar, in which lie all the workable beds of coal that have as yet been met with in the Wurdha field. The only subtractions that have to be made are of the eight square miles occupied by the Talchira, the 10 square miles occupied by the Barakars, and a few miles for the overlapping of the Kamthis, say 10 square miles, or a total of 28 square miles. The area of the field is 149 square miles. The average thickness of the coal is 40 feet; one of the borings showing seams aggregating 70 feet in thickness. The total amount of coal is therefore 148.— $28 \frac{1}{2} \times 40 + 1,000,000$  or 4,840,000,000 tons. Dr. Oldham is understood to have estimated the quantity at 484 millions of tons: but this had reference merely to the amount which may be considered economically accessible according to the present system of working in India, and the generally received ideas as regards workable depth. This amount, however, would at the present rate of consumption of coal in India last for 800 years."

310. The whole of that portion of the field which is situated on the western or Berar side of the Wurdha has this great advantage,

that all the coal is found at a comparatively easy working depth. The further researches have been pushed, the more valuable the coal-fields have proved. From accounts lately received, the latest boring put down at a place called Pisga, struck coal at 77 feet from the surface, and pierced 30 feet of coal without passing through the seam. The coal thus brought to light has been pronounced "of far superior quality to any yet found." Experiments made by the Great Indian Peninsula Railway Company, with specimens of Chanda coal, show that very considerable advantage would be gained by the Railway Company in using this coal. Even were we to assume that two tons of Chanda coal would be required to do the work of only one ton of best English coal, still the saving would probably amount to not less than ten rupees, or £1 on an average, on every ton of coal now consumed.

*Iron.*—P. 311. Recent geological researches have also led to the discovery of some very valuable beds of iron ore in the Woon district south of Yeotmahal. These, no doubt, were worked many hundreds of years ago, but were very likely abandoned for want of proper fuel. In former years they were made the subject of a report by the late Mr. Mulheran, who mentioned Yeotmahal and Oomrawuttee as rich in iron deposits, and added that Yeotmahal alone could yield iron sufficient to supply all the railways in India. Some of the beds are now reported to have been examined, and the minimum thickness shown is stated at nine feet of ore. In one place a bed of 17 feet in thickness was found. The assay of different specimens of this ore showed that it contained an average percentage of from 53 to 68·5 of iron: and specimens of Slag gave, under assay, as high a percentage as 34·8 of iron.

312. The following remarks by the officiating superintending engineer, Hyderabad Assigned District, may form a fitting conclusion to this section.

"The value of these discoveries," writes Major Mayne, "may literally be said to be incalculable. The existence of iron ores, no doubt, has long been known, but from the difficulty of access to them, and the scarcity of fuel, and also from experiments in the smelting of iron in other parts of India, there was nothing very encouraging to attempt the working of them. But now it is shown that alongside of iron of a most valuable description, for a length of ten miles or more, lies the fuel and limestone flux to work it. A railway could be carried down to the very heart of these fields at a comparatively very moderate cost, and is now under consideration of the Government of India. By running it to Davergaon, a station on the G. I. P. Railway, only one river of any importance has to be crossed, and a Railway could be constructed at a cost of about £4000 per mile. These iron ores and coal-fields are certainly deserving of the notice of capitalists, and every encouragement should be given to any pioneers who would undertake to commence work. No doubt, here lies the site of the future 'Black Country' of India."

Extract from Administration Report, 1870-71, by the same. After recapitulation of the above results, Mr. Saunders proceeds to say, page 213 :—

“Early in the year under review, the executive charge of the boring operations for the further examination of the field was carried on under the orders of the Government of India to the local authorities, the Geological Survey retaining the professional direction of the works.

“Application was made to the Government of India for the sanction of establishments both for completing the exploration, and for the experimental working of the coal-field. With the latter object, it was proposed to employ a mining engineer to sink one or two trial shafts, and get up a sufficient quantity of coal to allow of actual trial being made as to its qualities for locomotive purposes on the railway. Boring was carried on by Mr. Smyth to the setting in of the rains of 1870, by which time bore-holes had been sunk at the following places, Bellora, Nilja, Janara, Boregaon, Gaori, Rajni, Sakri, Pisgaon, and Manki. Some of these were sunk less with the expectation of actually striking coal, than with the object of defining the limits of the various strata. Good coal was met with at four places, Nilja, Junara, Rajni and Pisgaon.

“As it was evidently necessary to supplement the borings with trial shafts, arrangements were made, after the rains, to carry out the proposals submitted earlier in the year to the Government of India. A mining engineer, Mr. Bourne, was provisionally engaged; tools and plant were collected, and in March, 1871, a shaft was commenced at Pisgaon, and sunk 19 feet. This site had been selected after personal inspection, by the superintending engineer, and on the advice of the Geological and District authorities, as in all respects for a trial pit. But just as everything was in full working order, and hopes had begun to be entertained that in less than a month coal would be delivered at the railway ready for trial, then instructions were received to limit the operations in boring, and to stop the shaft. These orders were, on reconsideration, modified by the Government of India; but this was not done till the season was too far advanced for the work being pushed on, as it will now be resumed as soon as the cold weather sets in.

“The progress made has therefore been limited to extending and completing the exploration of the northern portion of the field explored by Mr. Hughes in 1869-70. The past year's work has had the advantage of Mr. Hughes' own guidance and advice, as well as, for a part of the time, his personal presence. It is to be regretted that ill health compelled him to leave before the end of the season.”

In regard to the southern and south-eastern extension of this coal-field and the Damuda and other series connected with coal, Mr. Blanford reports in vol. iv., part 2, of the Records of the Geological Society, 1871, that—

"Recent explorations in the Godavery Valley below Sioncha, and in parts of the adjoining country, have enabled me to ascertain that a very large area is occupied by representatives of the various formations which have been described in Bengal, and the central provinces under the names of Tanchit, Damuda, and Talchir. The occurrence of sandstone in the bed of the Godavery, and along its banks, throughout a large portion of the rivers course below Sironcha, was, I believe, first made known by Mr. Wall in the Madras Journal of Art and Science, New Series, vol. ii. It now appears that the sedimentary beds belonging to the Damuda group, and its associates, extend, apparently without a single break, from the neighbourhood of Mangli and Phisdura to Lingulá on the Godavery, just above the top of the first barrier, and 14 miles above Damagoodium; or throughout, a distance of 200 miles. These beds, as will presently be shown, extend far to the southwards."

Mr. Blanford then proceeds to explain the several areas over which these sand-stone series extends, which is principally to the south and west, for a long distance into His Highness the Nizam's dominions, and to the south-east as far as Rajah-mundri, extending to the banks of the Godavery near Palaveram, below the great gorge in the Metamorphic rocks, through which the river runs. At Pangudi, near Rajahmundri, the sandstones are covered up by the bedded Dolorites of the Deccan Trap, just as 300 miles to the north-west the same sandstones in the districts of Chanda and South-east Berar disappear beneath the same trap on the eastern range of the great basaltic area of the Deccan.

It must not be understood, however, that the whole of these Godavery sandstones are of the Damada or coal-bearing series. These only occur here and there, or can only be seen in certain localities where they can be observed by denudations or in the beds of rivers; but wherever they do occur coal is present more or less, in all of them. A very great portion of this large area is covered with forest, and with superficial clays and sand, so that any exploration of the whole of the tract would be attended with great labour and would require much time.

"Let it not be supposed," continues Mr. Blanford, "that this conclusion is a mere abstract scientific matter interesting perhaps to Geologists, but of no importance to the world in general. In reality, it involves a most serious economic question. It is quite unnecessary to remark that the discovery of coal in the Madras Presidency is a great desideratum. Hitherto, despite much research, neither coal, nor the rocks with which coal is associated in India, have been met with in any part of the country south of the Godavery. The tracing, therefore, into the Madras Presidency, of sandstones belonging to the great series of which the coal-bearing beds of Bengal form a portion is of great interest and importance, because there is a probability of the coal-bearing beds being associated with them. The greater part of the

working season of 1870-71 has been devoted to the very important borings for coal is the Godavery, and I have been unable to give nearly sufficient time to the examination of the Ellore and Rajahmandri country, to enable me to ascertain with certainty the presence or absence of Damuda beds."

I must here, in justice to the memory of two old and valued friends, both dead for many years, mention, that the first perfect discovery of the fossil bearing sandstones series of the lower Godavery was made by Dr. Bell, who, belonging to the Hyderabad Contingent force, was employed on account of his great scientific skill, as statistical reporter for the eastern province of H. H. the Nizam's dominions, under the orders of the Resident at Hyderabad. Dr. Bell was very sanguine as to the discovery of coal, and made a large collection of fossils, but fell a victim to fever contracted in the course of his explorations. He was succeeded by Dr. Alexander Walker, a man of equal zeal and scientific attainment as a geologist, who took up the thread of his predecessor's work, and actually discovered coal in the Wurdha, near Sironcha, at a village named Koka, in 1841. He even began afterwards a boring operation, which would, there is little doubt, have decided the question of coal in seams; for the locality of his discovery is in the southern portion of the Berar coal-field, on the west coast of the Wurdha. Unfortunately the boring was sunk too near the river, and became impossible of prosecution from the floods; and, after Dr. Walker's accidental death, the operation was not renewed till taken up by the authorities of the central provinces, and the Geological Survey.

*General Considerations.*—In conclusion, I beg to point out the evident advantages of the discovery and working of the several coal-fields which I have noticed. First, the Nerbudda coal-field has been opened by two companies—the Nerbudda coal and iron, and the Sita-riva. It is situated near the Great Eastern Railway, and can supply coal fit for working purposes, nearly at the centre of its length. In the eastern portions of the line the Bengal (Ranigunje) coal is used. On the western, coal from England; both supplies necessarily increasing in cost as distance from the sources of supply is reached. A supply, which is even as yet of fair quality, and may improve with deeper workings, running midway between the extremities, must be considered of the very highest economic value. Mr. Medlicott's report on the Mohpani coal-field, which includes the Nerbudda and Sita-riva Companies' works only, shows that a very abundant supply exists in that locality, which will last for years to come; but there is every reason to suppose that as the Damuda coal-bearing rocks extend as far south-west as the Tawa valley, and coal-bearing measures as far as a point thirty miles north-east of Jubbulpoor, a total direct distance of 180 miles or thereabouts, coal may be found by borings, or otherwise by exploration over a great part of its length and breadth of this formation, and promises a practically unlimited supply, both as to quantity and

value; for as yet, mining operations have been confined to the most promising locality of outcrop, which, perhaps, is by no means the best or surest indication either of quantity or quality. It is true that the outcrops in the Tawa valley are, compared with those of Mohpani, of apparently small value; but they prove indisputably the continuance of the Damuda beds, while the intermediate tract below the ridge which forms the basin of the Nerbudda does not alter in geologic structure in any part, and is, as yet, untested by borings, or even by superficial exploration.

*Berar and Chanda.*—These fields are even more important in an economic point of view than the Mohpani. You will observe by the map that the railway from Bombay bifurcates at a point in the province of Khandesh, that proceeding north-east of Jubbulpore, being the East Indian line, the other, after traversing the valley of Berar nearly due east as far as Nagpoor, turns northwards and rejoins the East Indian at Jubbulpore. This line of railway is part of the Great Indian Peninsula series. Now, at a point half its entire length, it will be observed that the Berar and Chanda coal-fields occur, so that when boring operations begin in earnest, the supply of coal will not only thoroughly provide fuel for the whole of this branch line, but will be available for a much greater development of the railway system of India, and render it entirely independent of supply of coal either from England or from Bengal. The only help required is a branch railway to the Berar coal-field, which, as has been explained, is practically the best of the two; and a convenient point of it could be reached at 30 to 35 miles distance, at the moderate cost, as estimated, of £4000 per mile. The surface is indeed nearly level throughout, and two small streams which require bridges are of no particular moment. This line has not, however, been begun, but it may be hoped will not long be delayed; nor does the wonderfully advantageous position of this great coal-field, which as even imperfectly ascertained, now amounts to a thousand square miles in area, affect the supply of the G. I. P. Railway only. It appears to me to decide the locality of a vast extension of the whole railway system of India, and for these reasons :—

In the south of the Berar coal-field, which, as a portion of H. H. the Nizam's dominions, is under British administration, lie large districts of H. Highness's territory, into which the Damuda series of rocks in continuance of the Berar fields have been traced, with corresponding discoveries of coal in many places. This area is now under exploration, under the direction of Sir Salar Jung, G. C. S. I., the present most enlightened Minister of the Government of H. H. the Nizam, for the purpose of constructing a railway from thence, or from some convenient point on the G. I. P. line, through Berar to Hyderabad. His Excellency Sir Salar Jung has already a railway under construction from the G. I. P. southern line at Gulburgah to Hyderabad, which will probably be finished by the end of this year. There will be nothing therefore to

prevent the commencement of a line to the Berar and Chanda coal-fields or to the Nagpore.

I need hardly dwell upon the importance of such a line. It would connect the great and rich city of Hyderabad with the north-east of India, opening out the whole of the eastern territory of H. H. the Nizam, rich in fine timber and other products which have now no possibility of reaching a profitable market; and passing through the Berar coal-fields would ensure supplies of fuel, as well to the Hyderabad and Gulburgah branch, as to the southern line from Gulburgah to Kurnool and Madras. Upon this point, as you will remember, Mr. Blanford lays great stress in the extract I have last quoted.

Again, it will be remembered, how earnest have been the labours to open the noble River Godavery to navigation; not only to open out the almost desolate provinces which lie on its lower portions, but to relieve Berar and Nagpore of the strain of carriage which the transit of the whole of these great cotton-producing territories maintains, and which grows greater and greater year by year. Now the southern portions of the Chanda and Berar coal-fields rest upon the Wurdha and Pranhecta rivers, which, up to these coal-fields, form the upper portions of the Godavery navigation scheme in progress of execution. The river steamers will not, therefore, only be coaled themselves, but will be able to transport Berar coal to the coast for the use of shipping, while on Mr. Blanford's data it is very possible that coal may be found in the Damooda series to Rajahmundri, or to the very mouth of the river. In any case, the steam navigation in the Godavery would be independent of any supply of coal from England, which was assumed as the great obstacle to its being ever attempted—because it could draw its supplies from Berar, a source of supply practically exhaustless for centuries to come.

I have already brought to notice, in this Paper, the enormous coal deposits at Korba, Chitrigurh, Jushpore, in the Chutteesgurh group, Jushpore and Oodipore districts of the central provinces. That at Korba, though very cursorily explored by Mr. Blanford, shows seams of fair and good coal-fields, 50 feet in thickness; and it is impossible to say what greater discoveries may not yet ensue over the very large field of Damooda rocks, connected, as it would appear on all sides, with the Korba formation.

If we carry on the line from the Berar coal-field through Korba, Chitri and Jushpore, we find it leads direct to the great Damuda beds at Ranigunje, where, I suppose, it terminates, as all beyond that, across the Ganges, is nearly pure alluvium. If, then, Ranigunje, on the Damooda, be the terminus, we find a continuous line of outcrops of coal of a very rich character, in exactly the same Geological character of rocks, from Ranigunje to Sironcha on the Wurdha, so far as is actually known, and which may be extended still further, southwards and eastwards. The portion between Ranigunje and Korba, and between Korba and

the Berar field, may here and there be overlaid by trap, Mahadéva sandstone, and other rocks; but it seems to be quite clear that wherever sufficient denudation has taken place the Damooda rocks appear, that they have the same or nearly the same horizon; that they have not been much disturbed; and lie on the Talchir series as their foundation.

Now, if the Hyderabad Government, as is most probable under its present admirable management, constructs a line of railway to the Berar coal-fields, and to a point on the G. I. P. line, what is to prevent an extension of the line *via* Korba and Jushpore to Calcutta or Ranigunje? There are ample depots of fuel by the way at convenient distances, already provided by nature; and we may well assume that, were a strict investigation by borings instituted, other coal deposits would in time appear. The great Geological fact of the continuance of the Damooda rocks from Ranigunje to the Godavery cannot be disputed, and the facts of the series everywhere containing more or less coal is equally incontrovertible under the evidence which the proceedings of the Geological Survey in India affords already and which, perhaps, is yet in its least development.

And I may state, in conclusion, that for the most part, the whole of this great length of country forms as it were a natural valley, with but comparatively few intersections or obstacles to the construction of the railway. It may be delayed for many years, but that it will be constructed finally, I myself have no doubt; and, when in use, will rescue from their present obscurity, and, comparatively speaking, valueless condition, tens of thousands of square miles of fertile country, and millions of people, now without a chance of competing with the rest of India.

XXIX.—ANALYSIS OF THE LEITRIM COAL, WITH REMARKS ON THE COAL AREA OF THE DISTRICT. By R. J. CRUISE, M. R. I. A.

[Read 9th April, 1873.]

THE paramount importance the coal question has assumed, not only to the manufacturer, but to every individual member of the community, must be my apology, if apology be needed, for trespassing on your attention to-night with this Paper, the object of which is to show the value, from a commercial point of view, of the Leitrim coals.

As I have been for some time engaged in the survey of the district for the Geological Survey of Ireland, I have had a fair opportunity of forming an opinion on the amount of coal it contains, and the facility with which it can be worked.

The Connaught coal-field is divided by Lough Allen—the Arigna district lying on the west, and the Slieve-an-Ierin on the east.

The greater part of the Arigna district is worked by the Lough Allen Coal and Iron Company (Limited), and it is from their works that the present samples have been taken. There are three seams of coal, of which the middle one only has hitherto been worked.

The specimens selected for analysis have been taken from three different parts of the district, as will be seen on reference to the Map, in order to arrive at a conclusion as to the average character of the coals.

The coal at present raised is of a rather brittle character, and will not bear much handling without breaking up, but will be found firmer when the workings are carried further into the seams, as is evidenced by the more compact nature of the specimens from Aughabehy and Selteneaveeny, as compared with those from Derrinavegey, which have been taken from near the outcrop. The coal is between bituminous and anthracite. It does not ignite readily, but when once kindled makes an excellent lasting fire, burning freely and with a steady heat. It does not contain sufficient volatile matter to be advantageously employed for the manufacture of gas, but would make a first-class coke for iron smelting. Its heating power is high, and it would therefore make a good steam coal.

It is certainly not equal as house coal to the better varieties of English coal, but will compare not unfavourably with most of the coals so largely imported into this city from England, Scotland, and Wales, while it is decidedly superior to some of them.

On analysis of the three samples, with a view of ascertaining the value of the coal as a fuel, the following results were obtained :—

ARIGNA COALS.			
	Selteneaveeny Pit.	Aughabehy Pit.	Derrinavegey Pit.
Water, . . . . .	0·852	0·92	1·16
Volatile Matter, . . . .	20·11	17·68	14·55
Carbon, . . . . .	70·13	70·37	74·85
Ash, . . . . .	7·24	9·80	9·01
	98·332	98·77	99·57
Specific Gravity, . . . .	1·334	1·339	1·416
Coke left by each Coal, . .	79·89	82·32	85·45
Ash in Coke, . . . . .	9·76	11·95	10·60
Lbs. of water evaporated from 100° C. by 1 lb. Coal, . .	11·55	Heating Power of Coal.	
		10·61	13·42

It is much to be regretted that so extensive a tract of coal-bearing ground should be allowed to remain unworked at the present time, when an absolute coal famine may be said to exist. The situation of the seams is most favourable for working, as they lie almost horizontally cropping out along the sides of the hill.

The Slieve-an-Ierin beds, comprising several thousand acres of coal-bearing strata, remain practically untouched, and would prove a most profitable investment for some of the capital at present lying dormant, or producing an almost nominal interest, if a few of the wealthy gentlemen in the country could be induced to form an association for the working of them.

Labour is plentiful and cheap in the neighbourhood, and by the introduction of coal-cutting machinery, and wire tramways to convey the coal to the lake, the cost of production and transit would be greatly reduced. There is canal communication between the lake and M. G. W. R.

It will be seen on comparison with the following table of analyses of other coals that those from the Arigna district correspond very closely in the constituent parts that make a good fuel:—

	Resolven (Welsh).	Hedley's Hartley (Newcastle).	Arigna Coal, mean of samples.
Coke, . . . . .	88.9	72.81	17.45
Vol, . . . . .	17.1	27.69	82.55
Ash, . . . . .	9.41	9.12	88

**XXX.—EXAMINATION OF LOUGH ALLEN COAL, FROM ARIGNA DISTRICT, COUNTY LEITRIM. By L. STUDDERT, LL. D., ex-S. T. C. D.**

[Received for 9th April; read May 14th, 1873.]

HAVING obtained, through my friend Mr. F. Hogan, of the Grand Canal Company's Directory, samples of the coal used for the Company's Shannon steamers, it seemed a matter of present interest to examine that coal with respect to its industrial value, so far as it can be ascertained by analysis of the coal, and the determination of its calorific power: this investigation was conducted in the Laboratory of the Royal College of Science, and under the direction there of Professor Galloway.

The Canal Company obtained the coal from the mine on the land of Mr. Patrick Walsh, of Ballyfarnon, near Arigna, county Leitrim.

It has been lately examined by Dr. Cameron; but that chemist did not determine, as would appear from his report, the coal's calorific power;

either by experiment, or by calculating that power or the calorific intensity from the coal's elementary composition: he reported, in print, only the *ultimate composition* of the coal; and the percentage of *coke* it yielded.

However, here would seem some mistake; for that report states 78·7 as the total percentage of carbon; yet the coal is reported as yielding 87·00 per cent. of coke, even after *deducting* ash: and according to my analysis it yields 15·63 per cent. of *volatile matter*.

As it is always desirable to determine the calorific power by *experiment*, rather than to deduce it by calculation from the coal's elementary composition; and as Berthier's method of determining heating power is considered inaccurate, the mode I employed for arriving at the absolute heating power was by the simple and ingenious apparatus invented by Mr. Lewis Thompson.

I found the *ash* to vary in different samples of the coal: in one sample estimated, it rose to 27·7 per cent.; the lowest amount found was 17·7 per cent.; whilst the sample employed for estimating the proximate composition of the coal—hereinafter given—contained 21·27 per cent. of ash.

The *sulphur*, also, was found to vary—but slightly—in the different samples examined for that element.

The following are my results for SPECIFIC GRAVITY; PROXIMATE COMPOSITION; and HEATING POWER of this coal.

*Specific Gravity*, - - - - 1·382.

PROXIMATE COMPOSITION :

<i>Water</i> ,	-	-	-	-	-	00·87
<i>Volatile Matter</i> ,	-	-	-	-	-	15·63
<i>Coke</i> ,	-	-	-	-	-	62·23
<i>Ash</i> ,	-	-	-	-	-	21·27
						<hr/>
						100·00

Estimation of the SULPHUR in the Coal.

The sample of coal containing 27·7 *per cent.* of ash } 0·7 *per cent.* of  
yielded - - - - - } sulphur.

The sample containing 17·7 p. c. of ash yielded 0·64 p. c. sulphur.

This was determined by igniting, in a combustion tube, a weighed quantity of the coal, mixed with pure sodic carbonate, and potassic chlorate, afterwards dissolving the ignited mass in water, acidulating the solution with hydrochloric acid, precipitating with baric chloride, and then proceeding in the usual way for the determination of the sulphur.

Estimation of the Sulphur in the COKE.

The 62·23 *per cent.* of coke, obtained in the foregoing proximate analysis of the coal, yielded 0·5 *per cent.* of sulphur.

Therefore from the *mean* of those two determinations of the sulphur

in the coal, subtracting the percentage of sulphur in the coke, the remainder was the percentage of sulphur *volatilized*: thus—

Total Sulphur,	-	-	-	0.67	<i>per cent.</i>
Sulphur <i>not</i> volatilized,	-	-	-	0.50	„
Sulphur volatilized,	-	-	-	0.17	„

As to the sulphur in the *coke*, it was determined by fusing, in a crucible, a weighed quantity of the coke with pure sodic carbonate and potassic nitrate, treating the fused mass with water, acidulating that solution with hydrochloric acid, then precipitating with baric chloride, and proceeding as usual to complete the determination of the sulphur.

#### HEATING POWER.

The *absolute heating power* is this: 9.15 lbs. of water, at 212° F., converted into steam by *one* lb. of the coal: and 789.98 lbs. of water, at 212° F. converted into steam by one *cubic foot* of the coal.

This is the heating power of that sample containing the mean amount of ash; and the proximate constitution of which I have given above: but for the sample containing *least* ash, the heating power was this:—12.23 lbs. of water, at 212° F., converted into steam by *one* lb. of that sample: and 1056.53 lbs. of water, at 212° F., converted into steam by *one cubic foot* of that coal.

Thus the coal I examined is inferior to samples from the Arigna district, which were examined some years ago in this Laboratory—both as regards calorific power and the quantity of ash contained; for these previous examinations, published at the time in “The Technologist,” found the ash to vary from 4 up to 7.5 per cent. only: and the absolute heating power was found—for the coal described as “from the detached field north of Arigna valley, Settanaskagh Colliery, county Leitrim,” to be as follows:—13.47 lbs. of water, at 212° F., converted into steam by one lb. of that coal: and 1246 lbs. of water, at 212° F., converted into steam by one cubic foot of same.

Again, for that described as “Bituminous coal from Lough Allen district, Leitrim coal field,” the heating power was found to be this:—12.65 lbs. of water, at 212° F., converted into steam by one lb. of that coal: and 1082.37 lbs. of water, at 212° F., converted into steam by one cubic foot of that coal.

And again, for what is described as “Coal from the third seam from Gubburudda Colliery, valley of Arigna, Connaught coal field,” the heating power was found to be as follows:—14.29 lbs. of water, at 212° F., converted into steam by one lb. of that sample of coal: and 1142 lbs. of water, at 212° F., converted into steam by one cubic foot of that coal.

These three previous specimens of the coal seem little inferior, as regards calorific power, to *best* Newcastle, Scotch, or Welch coal, when estimated for heating power by Thompson’s apparatus, as given in Mr. Cleg’s book “On the Manufacture and Distribution of Coal Gas,” p. 87:

for the calorific power of the Newcastle was so found to be 15 to 16; of the Scotch, 17 to 18; and of the best Welch Anthracite, 13 to 14½ lbs. of water, respectively, converted into steam by one lb. of those three last-mentioned coals respectively.

From my analysis it will be seen that the coal from Lough Allen belongs to the class of coal termed "Bituminous." It breaks easily into rectangular pieces; and it makes no noise in burning; nor gives off, then, any sulphurous smell.

XXXI.—THE CARBONIFEROUS INGENITE ROCKS OF THE COUNTY LIMERICK. By G. H. KINAHAN, M. R. I. A., &c.

[Read May 7th, 1873.]

IN the last Geological Magazine (April, 1873), has appeared a Paper that was read before the Society, on the Carboniferous Ingenite Rocks of the County Limerick.\* This Paper is likely to mislead, both on account of its title and the statement contained in it, that the specimens described "may be regarded as a fair representative of the Limerick Carboniferous Melaphyre." The exotic rocks of Carboniferous age in this county, besides the tuffs and agglomerates, may be classed in four groups:—

I. *Elvanytes* (Quartziferous porphyry).

II. Basic felstone; the *Eurytes* of Daubuisson.

III. *Melaphyres* (Felspar and pyroxene with or without amphibole), and IV. *Aphanyte-dolerite*.

The Elvanytes occur in protrusions in the lower or stratified portion of the lower limestone, while the others for the most part are interstratified in the limestone on two distinct geological horizons. The first were only observed in three or four isolated tracts; the second and third are the typical igneous rocks of the country, while the rocks of the fourth group were only found in a few localities.

The elvanytes range from nearly compact to highly crystalline, the centre of the masses being more or less granitoid, but they cannot be properly examined, as only a few surface quarries have been opened into them; generally they seem to be felsitic or felspathic, but in one locality they are known to be hornblendic. The Eurytes range from a compact to a highly porphyritic and granular rock, which in places may be even granitoid, and seems to be passing into Elvanyte. The Melaphyres are more or less crystalline, and in places contain distinct crystals of Amphibole, while in others they seem to pass into the sub-

\* On the Microscopic Structure of the Limerick Trap-rock, by Professor E. Hull.

variety *Peridoleryte*, but in none of the Limerick specimens of the latter rock were the olivine crystals so distinct as in specimens procured from the enginite rocks at Croghan Hill, north of Philipstown, King's County, and the latter rocks seem to be on the same geological horizon as the lower zone of engenite carboniferous rocks in the County Limerick. The Aphanite-melaphyres, from which the specimens described in the Paper referred to (excepting Nos. 7 and 10) were procured, occur only in very subordinate masses associated with the Eurytes and Melaphyres. Generally they are interstratified and contemporaneous with the other rocks, but in two places at least they are probably protruded or intrusive. They, however, were specially noted by myself and my colleague, J. O'Kelly (not Mr. Wynne, as stated in the Paper previously referred to), on account of their being so similar in aspect to some of the whinstones of Tertiary age in the County Antrim, and other parts of the province of Ulster.

From the above it will appear the rocks examined do not represent the "Limerick trap-rocks," or even the "Carboniferous Melaphyres:" and in conclusion I may state that the rocks examined, excepting Nos. 7 and 10, were collected by me not to represent the Limerick trap-rocks, but the rocks called Basalt by the late J. Bute Jukes, F. R. S.

**XXXII.—ON THE OCCURRENCE OF SILICEOUS NODULAR BROWN HÆMATITE (GÖTHITE) IN THE CARBONIFEROUS LIMESTONE BEDS, NEAR COOKSTOWN, CO. TYRONE; WITH ANALYSIS; AND NOTE ON ITS FORMATION BY CHEMICAL ALTERATION FROM ORDINARY CLAY-IRONSTONE.**  
By EDWARD T. HARDMAN, of the Geological Survey of Ireland;  
Associate of the Royal College of Science, Dublin.

[Read 14th May, 1873.]

THE ore which is the subject of this paper occurs in rather an uncommon manner. Its existence, however, has been known for a very considerable period, and it is said to have been worked at least 250 years ago. I believe it is this that is referred to in Dr. Boate's quaint work, "*Ireland's Naturell History*,"\* as being found "by the side of the rivulet Lishan, not far from Lough Neagh," although he classes it with the ordinary clay-ironstones, which it certainly does not resemble either in composition or appearance.†

\* Published 1652.

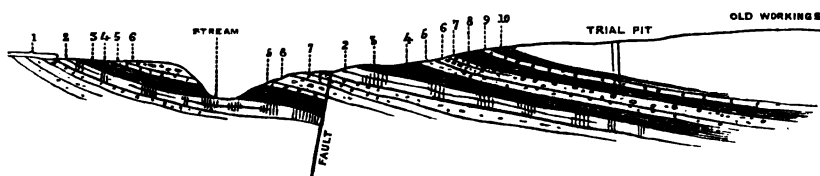
† It is also referred to by Sir Richard Griffith, in his "*Catalogue of Fossil and Mining Localities*," Jour. Geol. Soc. Ir., Vol. IX., and its position marked on his map; and it is mentioned in Portlock's "*Geological Report, &c.*," but, so far as I am aware, it has never been described before.

It is found at a place called Cove Bridge, near Lissan, in the townlands of Unagh and Tullycall, about two miles N. W. of Cookstown. Here there are numerous traces of old workings; and in the rivulet which separates the townlands, as well as in various quarries and rock exposures hard by, sufficient evidence is to be had to enable one to determine with tolerable exactness the position and mode of occurrence of this singular deposit. The section shows a succession of beds of coarse and fine yellow, purple, and reddish sandstones, and grits—passing into quartzose conglomerates—interstratified with beds of variously coloured sandy and clayey ferruginous shales, and several limestones, marbly and dolomitic, and closely resembling some of the Armagh beds. In the shales are hollow nodules of the hæmatite, sometimes very sparingly distributed, but in at least one bed very abundant. This bed, I am informed by the men who had proved it—for it does not appear at surface—is 4 ft. 6 in. thick, the shale being crammed with nodules; and it has been worked to some little extent. Two pits were opened on it about eighteen months ago; but, like all mines of this kind, they were found difficult to keep in order, and therefore dangerous to work, and the miners took fright, and gave up the attempt.

The following is a section of the strata in which the ore lies, compiled partly from information and partly from my own observation, commencing at the top with the beds passed through in the pits above referred to.

Fig. 1.

Sketch Section to show mode of occurrence of the Hæmatite deposit in the Carboniferous Limestone beds near Cookstown, Co. Tyrone.



Longitudinal scale, 12 in. to one mile.  
Vertical " about 240 ft. to one inch.  
Thickness of beds much exaggerated.

## SECTION NEAR COVE BRIDGE.

				Ft.	In.	
Probably lower Carbon- iferous series.	11	Drift, &c., and	- - -	about	55	0
	10	Shale (a couple of feet thick) with some hæmatite nodules	- - -			
	9	Coarse rotten sandstone	- - -		3	0
	8	Red clayey ferruginous shale, full of hæma- tite nodules (workable bed)	- - -		4	6
	7	Whitish sandstone	- - -			
	6	Hard reddish quartzose conglomerate (calcareous)	- - -		1	6
	5	Rotten yellow decomposed clayey sand- stone	- - -		2	0
	4	Reddish shale with hæmatite nodules	- - -		1	0
	3	Yellow and brown sandy clay, with occa- sional hæmatite nodules	- - -		2	0
	2	Purple, grey and marbly massive limestone	- - -		8	0
	1	White, yellow and purple coarse grits and sandstones, streaked. Thickness not seen.	- - -			
				77	0	

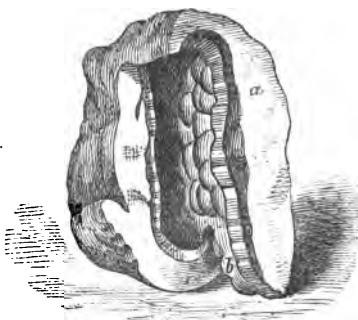
The above is only approximately correct, as the junction of some of the beds is not visible.

The relative position of the strata can, however, be distinctly traced, and the interstratification of the ore-filled shales fully made out. They do not, like others of the kind, lie in veins, pockets, or erosions in the limestone. In one place, indeed, there is a slight depression in the limestone under the shale beds, but it is difficult to decide whether it is due to erosion, or to a small fault.

It is probable that, over these, other workable beds of ore must exist, because the mass of old workings are some distance to the dip of this place; and it is not at all likely that the ancient miners would venture to a depth sufficient to catch the 4 ft. 6 in. seam there.

The nodules are mineralogically very peculiar. They are usually in the form of a hollow shell, of say a quarter of an inch in thickness. The greater part of this is made up of a very hard compact siliceous brown hæmatite, of a dark brown colour, but the interior is covered with a thin coating of fibrous and mammillated limonite. When they are found *in situ*, and perfect, they often contain a kind of nucleus of sandy shale or clay.

The shale in which they occur is generally ochrey, red, and seems to be highly ferruginous. Being apparently very aluminous, as well



About half the natural scale.

Fig. 2—Hollow Nodule of Brown Hæmatite from shale beds (8) near Cookstown.  
(a) Shell of compact Hæmatite.  
(b) Internal coating of mamillated fibrous Brown Hæmatite.

as in parts calcareous, it might be very advantageously used as a flux for the ore, were it worked. In this way the whole bed might perhaps be utilized.

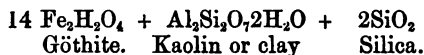
That this ore is of excellent quality for the smelter will be perceived from the following analysis. The specimens used were taken from a large heap, left after the new workings were discontinued, and were not the very best,\* for those had been taken away before; and Dr. Ritchie of Belfast informed me, that some he had had estimated yielded over 60 per cent. of iron.

#### ANALYSIS OF ORE.

Fe <sub>2</sub> O <sub>3</sub>	.	.	.	74.56
FeO	.	.	.	a trace.
MgO	.	.	.	0.044
CaO	.	.	.	a trace.
SiO <sub>2</sub> , &c.	.	.	.	9.42 †
Al <sub>2</sub> O <sub>3</sub>	.	.	.	3.51
Water combined	.	.	.	10.24
„ hygroscopic	.	.	.	2.90
MnO <sub>2</sub>	.	.	.	a trace.
CO <sub>2</sub>	.	.	.	a trace.
P <sub>2</sub> O <sub>5</sub>	.	.	.	a trace.
				100.674

Metallic Iron 52.20

This seems to give the composition of göthite‡ Fe<sub>2</sub>H<sub>2</sub>O<sub>4</sub>, a meta-hydrate, which is a usual form of brown hæmatite, together with a hydrous silicate of alumina, such as kaolin, and some free silica. It might be nearly expressed by the formula



\* I found even better specimens in appearance in the thin shale beds.

† Soluble silica together with insoluble residue, containing a little Al<sub>2</sub>O<sub>3</sub>.

‡ Manual of Geology (Jukes & Geikie), p. 68.

There was a total absence of sulphur, and the merest trace of phosphoric acid could only be detected by the most delicate test. Thus the ore is extremely well suited for the manufacture of Bessemer steel.

For a brown hæmatite the percentage of iron is very high, and its composition seems to render it well adapted for admixture with clay-ironstones, or with the aluminous ore of Antrim. As to its extent, it may run for a considerable distance to the south-east, and if the thickness and richness hold good, it may prove to be a very valuable deposit.

By the kind permission of Professor Galloway, the analysis was made in the Laboratory of the Royal College of Science, Dublin.

It appears to be a circumstance of some novelty to find an ore of this kind, as a bed or part of a bed in the carboniferous limestone, and interstratified with the rocks of that formation. In the North of England, where very extensive deposits of red and brown hæmatite are worked in the limestone, their true mode of occurrence is very doubtful: and for the most part it is believed that they either lie in cavities of erosion in the limestone, or in veins and lodes.\* In the Alston Moor district, however, brown iron ore occurs associated with the beds of clay ironstone lying between the "Great" and "Little" limestones, but it is considered to have some relation to the veins which traverse the district.† And although at Cleator in the Whitehaven district red hæmatite is found, apparently interbedded with shale and conglomerate, this seems to be thought to be by no means proved.

In at least one locality in England, hæmatite has been found, unmistakeably interbedded with the carboniferous rocks. Its position is given in a section of part of the old red sandstone and carboniferous rocks of Lower Purlieu, Forest of Dean, Gloucestershire,—in Sir Henry de la Beche's Memoir on the Formation of Rocks in South Wales and South Western England.‡ The section is chiefly made up of sandstones, shales and limestones,—like that at Cookstown, and massed together, is

	Fest.
Sandstones with shales, . . . . .	88
Limestone, . . . . .	90
Limestone with intermingled hæmatite, extensively worked, . . . . .	60
Limestone, . . . . .	330

\* Iron Ores of Great Britain, Part I., p. 14. W. W. Smyth (Mems. Geo. Sur. Gt. Brit).

† *Ibid.* pp. 14–17.

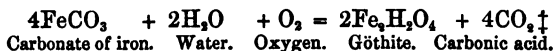
‡ Mems. Geo. Sur. Gt. Brit., Vol. I., pp. 128–130.

and Sir Henry de la Beche considers the occurrence of the ore in beds very unusual in the carboniferous limestone.

The above report, however, does not state in what form the hæmatite is found, whether in nodules, or amorphous or crystalline layers. And in fact, in only two instances can I discover any definite account of an iron ore existing in any quantity in the form of that under notice. It appears that in the Lower Greensand at Seend near Devizes, and in Buckinghamshire, nodules of brown limonite, often hollow and filled with white sand, are found in thick brown sand.\* The composition of that at Seend somewhat resembles that of the Cookstown ore.

A similar ore occurs associated with the clay ironstones of the Dungannon coal-field. A specimen I picked up at an old pit there was extremely like it, containing also a sandy nucleus; and in its analysis as given by Sir Robert Kane, who says, it has been found in abundance†—the resemblance is very close. After many searches, I was unable to find more than one sample of it.

This brings us to one of the most interesting points about the ore, namely, the mode of its formation. I believe it may be considered a kind of pseudomorphic product, the result of the chemical action of water carrying various substances in solution, on nodules of clay ironstone, the former occupants of these shale beds: and in order to arrive at the present state of the mineral, we must understand three distinct processes to have taken place. The clay ironstone nodules, of which numbers are found in the shales of the carboniferous rocks of the district, were first formed in the usual way by segregation of the highly ferruginous particles of the clays, &c., in which they occur. Then in the course of time, water passing through the variously constituted rocks over head, and therefore taking up alkaline silicates, carbonic acid, bicarbonate or hydrate of lime, and of course carrying oxygen, would gradually, by a long series of rather complex decompositions, completely or in part alter the clay ironstone. The carbonate of iron might undergo alteration by several reactions, the simplest of which would be the direct action of oxygen, thus:—



and the carbonic acid thus set free would no doubt react on a portion of the proto-silicate of iron in the clay ironstones, producing a fresh

\* Bauerman's Metallurgy of Iron, p. 76.

† Industrial Resources of Ireland, p. 127.

‡ Student's Manual of Geology, Jukes and Geikie, article by W. K. Sullivan, Ph. D.



Thus the clay-ironstone results in brown hæmatite, more or less free from siliceous and clayey particles, according to the extent to which the alteration has been carried. The final process seems to have been the deposition from solution of the thin internal layer of pure fibrous hydrate.

While it is thus shown how such a change is theoretically possible, it is satisfactory to obtain undoubted evidence that this metamorphosis of clay-ironstones, of various kinds, really does take place; and it may, I think, be proved pretty conclusively by the following example.

On the southern shore of Lough Neagh is found a great thickness of beds of—sometimes very arenaceous—pottery clays, with sand, and occasionally beds of lignite, besides concretionary sandstones, and nodules of clay-ironstones. The whole has been correlated with the Bovey Tracey deposit, but is, I believe, of somewhat more recent date.



Fig. 3—Nodule of Ironstone from later tertiary beds of Lough Neagh; partially altered.

- (a) Original Clay-ironstone forming interior nucleus.
- (b) Shell of pseudomorphic brown Hæmatite consequent on decomposition of (a).

The ironstones are very hard and compact,\* sometimes of a slightly greenish colour, and seem to consist chiefly of proto-silicate and carbonate of iron; but the outside is often composed of a thick crust of hard, close, siliceous brown hæmatite, evidently the fruit of the chemical alteration of the original nodule. One of these is figured in the cut (see Fig. 3). The external shell of hæmatite (b) is nearly a quarter of an inch thick. It almost completely encloses the unaltered ironstone, being broken to show the interior. A qualitative analysis was made by me of a portion of the unaltered part of one of these nodules, with the following result:—

It did not effervesce at all with dilute acid; but when powdered, and treated with strong hydrochloric acid, and gently heated, violent effervescence took place, and much carbonic acid was given off. The insoluble residue, consisting chiefly of silica, alumina, and a little peroxide of iron, was not unusually large, compared with the bulk taken. The solution contained a very large amount of protoxide of iron, with alumina, and a trace of peroxide of iron. Only a very small trace of lime could be discovered: nothing else was looked for.

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\* And generally contain reed-like plants, still retaining the woody tissue.

Tabulated, for the sake of clearness, this gives—

SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> &c. (insoluble residue).					
Fe <sub>2</sub> O <sub>3</sub>	.	.	.	.	a trace.
FeO	.	.	.	.	in large quantity.
Al <sub>2</sub> O <sub>3</sub>	.	.	.	.	.
CaO	.	.	.	.	a trace.
CO <sub>2</sub>	.	.	.	.	in large quantity.

It was not considered necessary to make a quantitative examination, for the above could leave no doubt as to the composition of the nodule. It is a clay-ironstone, made up of carbonate of iron, protosilicate of iron, and clay, or silicate of alumina.

These specimens are therefore useful, in placing before us the exact method of transformation of clay-ironstone into nodular hæmatite. It is only by the infiltration of water, containing oxygen and other chemical agents that these could have been affected, for ordinary atmospheric air could have had no access to them, some of these tertiary ironstones having been got from beds of clay 20 feet thick, and often covered by from 10 to 30 feet of glacial drift. Indeed, the effect of the atmosphere would be merely to form a thin crust of brown oxide, which would not be likely to consolidate, but would be removed, almost as soon as formed, by the weather.\*

It seems worthy of remark, however, that these tertiary ironstones are very nearly as fully developed, both in their original and metamorphic stages, as their more ancient brethren of the carboniferous period. And it appears, that just as we have perfectly consolidated rocks of all ages, so with the power of water to produce complicated changes on all rocks through which it may be able to percolate, even when they are in part composed of constituents apparently so unsusceptible to its influence, or belong to a period that may be called the yesterday of geological history.

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\* The appearance of clay-ironstones which have been exposed to the weather for a long period, is very different from that of any of these: and the crust of very incoherent oxide is more highly hydrated, its composition being Fe<sub>4</sub>H<sub>6</sub>O<sub>9</sub>.—Manual of Geology (Jukes and Geikie), pp. 15 and 28.

**XXXIII.—ON ANALYSIS OF WHITE CHALK FROM THE COUNTY OF TYRONE, WITH NOTES ON THE OCCURRENCE OF ZINC THEREIN. BY EDWARD T. HARDMAN, of the Geological Survey of Ireland, Associate of the Royal College of Science, Dublin.**

[Read June 11, 1873.]

I WAS led to make this analysis with the view of determining whether the extreme hardness of the Irish Chalk was due to either a chemical, a mechanical, or calorific alteration, from the influence of the overlying basalt. If it were owing to chemical change, we should expect to find a large percentage of silicates, and a diminution in the amount of lime; if to the influence of heat, carbonic acid would be driven off, silica would be in excess, and the presence of the insoluble bases, such as the peroxide of iron, oxide of manganese, and alumina, would become more apparent; while, if a mechanical cause, or pressure, were the reason, no change would take place in the relative amount of the constituents. I believe the result will show that the induration of the Chalk must be set down to the latter cause—if to anything apart from the original formation of the rock—and that the power of alteration exerted over it by the heat of the molten basalt has been small indeed. At the same time a certain addition has been made to it by means of water holding chemical bodies in solution.

The following is the result of the analysis. The specimens were obtained from an old quarry in the townland of Legmurn, about a mile and a half north-east of Stewartstown. The Chalk is so indurated as to form in reality a hard splintery limestone :—

Ca CO <sub>3</sub> ,	. . .	97·320.	
Mg CO <sub>3</sub> ,	. . .	0·890.	
Si O <sub>2</sub> ,	. . .	0·527.	
Al <sub>2</sub> O <sub>3</sub> ,	. . .	0·273.	
Fe <sub>2</sub> O <sub>3</sub> ,	. . .	0·095.	
Fe O,	. . .	a trace.	
Zn O,	. . .	traces.	{ Very perceptible even in small quantities of the Chalk.
Ba O,	. . .	a trace.	
Sr O,	. . .	a trace.	
K <sub>2</sub> O,	{	. . .	Amount not estimated.
Na <sub>2</sub> O			

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99·105

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By the kind permission of Professor Galloway the quantitative analysis was made in the laboratory of the Royal College of Science, Dublin.

As the potash and soda were very small in quantity, it was not worth while to estimate them, and the residue insoluble in hydrochloric acid, amounting to but 1·565 grains in 297·5 of the limestone, was considered to be silica, being too small to analyse.

There is nothing remarkable about the other constituents, except the presence of zinc, which, I believe, it is unusual to find disseminated in an invisible form over a large extent of rock, even in trifling local amount.\*

I happened to discover its presence in the Chalk accidentally, while examining it in the wet way for titanous acid, which I imagined might be expected to result from the decomposition of titaniferous ferrite in the overlying basalt. The titanous acid did not reveal itself, but a strong indication of zinc appeared. I then determined to test it in the dry way; and on fusing some of the powdered Chalk with carbonate of soda on charcoal, I was able actually to reduce a small portion of the metal, so as to obtain a few spangles of it. These when subjected to the proper tests gave the usual reactions with the blow-pipe, which characterize zinc, and its compounds. I repeated this experiment several times with different specimens of the Chalk, and was able to satisfy myself fully on the presence of the metal in it.

As from some of the trials zinc appeared to be in such quantity as might be estimated; 297·5 grains of the powdered Chalk were taken, dissolved in hydrochloric acid, treated with sulphuretted hydrogen, on the expectation that some of the metal, such as copper, precipitable by it, were present. Silica, iron, and alumina were removed, and it was finally examined for zinc. This was unmistakeably proved to be present, but unfortunately in too small a quantity to weigh. In fact, it appears to be unequally disseminated through the rock, for while in some very small portions submitted to qualitative analysis it was extremely perceptible, yet in the larger quantity above-named it seemed disproportionately small.

It then became a question, whether the metal was a merely local deposit, or was widely scattered through a large area of the Chalk. I therefore examined a specimen of hard white Chalk from Slieve Gallion Carn, in the County Derry, some eight miles, as the crow flies, north-west of Legmurn. It occurs as an outlier on the new red sandstone, and underlies the basalt. The specimen obtained was but two feet below the basalt, but could not be distinguished in appearance from the other, which lies at some little distance from the edge of the dolerite. It contained a few slightly reddened flints, however. The examination was made for zinc, and was done as before by fusing

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\* At any rate I know of no published analyses of limestone or other rock, in which it has been already noticed.

a portion with carbonate of soda before the blowpipe.\* As was expected, the metal was again reduced, and was perfectly visible, apparently in the same quantity as in the first specimen. Its presence was then confirmed by other tests.

Although this of course affords no direct evidence as to the existence of the metal throughout the Chalk here, it is curious that it should be detected in samples procured at such a distance from each other if this were not so.

The idea then arose that it might have been carried down from the basalt in aqueous solution. Accordingly a piece of the basalt, which crops out about 160 yards north-east of the Chalk quarry in Legmurn was procured,† and examined in the same way as the other specimens. In this also zinc was discovered, and in very appreciable amount; so much so, that I doubt not, had I had time to make a quantitative examination I should have been able to estimate it.

There can be little doubt, therefore, that the zinc that occurs in the Chalk, probably as carbonate, which would be undistinguishable on inspection, has been carried down from the basalt in aqueous solution. In what form it exists there, however, must be uncertain.

‡[It is true that in most mineralogical works there is no direct mention of the occurrence of zinc compounds in igneous or volcanic rocks, but it seems to be implied in one or two instances; and it certainly appears to be quite possible that many of them would be formed both in the wet and in the igneous way in such rocks. At first sight it might be surprising that such a volatile metal as zinc would remain undissipated under the great heat of molten rock, yet several zinc minerals have been artificially formed in furnaces and under other applications of heat. Franklinite, a variety of magnetite containing zinc and magnesia, found workable in the metamorphic silurian limestone of New Jersey, has been imitated by Delesse, by the

\* Fletcher's hot blast gas blow-pipe was used; and by its means a comparatively large quantity of the powdered Chalk and basalt could be treated.

† The spot from which the basalt was obtained is about 300 yards from the Chalk quarry.

‡ The above bracketed portion was added after the Paper had been read, as the possibility of zinc occurring in the igneous rocks was disputed at the time. The method of analysis was also said to be unreliable; but it is a far more certain test for small quantities than the wet process. By it a metal was obtained. This was white and brittle: it dissolved readily in dilute hydrochloric acid; and the solution of the metal heated on charcoal with nitrate of cobalt gave a very distinct bright green incrustation. There is but one metal that exhibits all the above characteristics, and that is zinc.

Voltzite  $\text{Zn S} + \text{Zn O}$ , occurs at Rosieres, near Pont Gibeaud, Puy de Dome (Dana's "Mineralogy," p. 50). No mention is made of the rock in which it is found; but in Scrope's "Volcanoes of Central France," both in the maps, and in the letterpress (pp. 56, 57), the rocks of that neighbourhood are shown to be granite, and recent-basalt; no other than igneous rock being shown on the maps nearer than about 18,000 metres (Edition 1858).

action of sesqui-chloride of iron and chloride of zinc on lime, under the influence of heat.\* Zincite, or red oxide of zinc, has been obtained in the iron furnaces of Silesia, and New Jersey, and in Zinc furnaces at Siegen.† Blende has resulted artificially from subjecting heated oxide or silicate of zinc to the vapour of sulphur, and is found in the furnaces at the Freiburg smelting works.‡ “It occurs in both crystalline and sedimentary rocks.”§

Thus it appears to be quite possible for some zinc compounds to have had a contemporaneous origin with the basalt. On the other hand, the zinc may have been introduced at a later period by the agency of water, in the same way as carbonates of lime, magnesia, and iron have been, and the zeolites which are so abundant in that rock. In either way most of the zinc minerals might have been brought in. There is nothing therefore remarkable in the fact of the metal being detected; and it might be met with oftener, were it looked for during the analysis of rocks, just as other metals known to exist in certain rocks seldom appear in their published analyses.

It can only be a matter of surmise as yet, with regard to the forms in which the zinc exists in the basalt. A possibility might be suggested, however, that some of the magnetite which is found as an accessory mineral, in that of Antrim,|| may be of the variety franklinite. Some of the spinels too, with which this is allied,¶ and which themselves number a zinc compound, have been found in vesicular cavities of the volcanic rocks of Monte Somma;\*\* and at least one instance is given of the discovery of *metallic* zinc in basalt. It is said by G. Ulrich to have been found by a quarryman in a geode in basalt near Melbourne, Victoria, associated with Smithsonite and Cobalt-bloom: the specimen weighed 4½ ounces. Dana, however, considers the account to be somewhat doubtful.‡‡

With this exception the analysis shows nothing that could be ascribed to chemical alteration, nor has there been any loss of carbonic acid, so that the original heat of the superincumbent basalt, which has been so often relied on as the means of hardening the Chalk and reddening the flints, must be quite out of the question. Perhaps a great deal too much power has been granted to this agent, as may be conceded when we recollect the unaltered condition of the intervening

\* Dana's System of Mineralogy (1868), p. 153.

† Op. cit. p. 185. See also Percy's Metallurgy of Lead, p. 325.

‡ Op. cit. p. 50. § Op. cit. p. 49.

|| Professor Hull “On the Structure of Trap Rocks,” Geol. Mag., April, 1873, and Jour. Roy. Geol. Soc. Irel., vol. iii., current Part.

¶ Manual of Geology (Jukes and Geikie), p. 63 (Article by W. K. Sullivan, Ph. D.)

\*\* Cotta Rocks Classified and Described, p. 61.

‡‡ Dana's System of Mineralogy (1868), p. 17.

leaf-beds, and lignite, which do not appear to have been affected by it, although naturally very susceptible of its influence.\*

When, however, it is remembered that in the Hebrides the basalt reaches a thickness of between 3000 and 4000† feet, and that the Irish basalt, although now but from 500 to 1200 feet thick, may have had similar proportions, there is no difficulty in referring the consolidation of the Irish chalk to pressure alone, for taking the original thickness of the basalt at only 3000 feet, the pressure on each square yard of underlying Chalk would be about 2000 tons.

The analysis, which is extremely similar to one by Mr. Wonfor, of the Chalk of Cushendall, Co. Antrim,‡ shows that this is a limestone of very great purity, the percentage of siliceous matter being so small as to be quite insignificant. It would be therefore of the highest value in many chemical manufactures, especially that of Bleaching Powder. It is, however, remarkable that although in the North of Ireland an immense quantity of this material is used up, it is not made there, but is mostly imported from Glasgow and Lancashire, and so far as I know, there is not a single Chloride of Lime Works in Ulster.§

XXXIV.—ON THE SILICIFIED WOOD OF LOUGH NEAGH. By the REV. GEORGE MACLOSIE, M. A., LL. D. (Lond.).

[Read April 9, 1873.]

ALONG various parts of the shore of Lough Neagh, fragments of fossil wood are found, and from the creamy surface of bleached specimens it was concluded that they had once been the wood of the holly-tree. In former times whetstones were made of these, and vended over the country with the hawker's cry,

"Lough Neagh hones, Lough Neagh hones,  
You put them in sticks, and you take them out stones."

From early times the subject excited the curiosity of learned men, and towards the close of the last century the Royal Society caused inquiries to be made, to clear up the doubts in which it lay. In 1751

\* Bischof mentions that small pieces of clay-slate caught up in lava-beds were afterwards found to be quite unaltered.

† Manual of Geology (Jukes and Geikie), p. 690.

‡ Jour. Roy. Dub. Soc., July, 1860.

§ A quantity of the Antrim Chalk is, however, exported to England for manufacture there.

Dr. Barton published his great work on Lough Neagh, which contained an elaborate and reliable investigation of the petrifications. Since his time they have been discussed by Dubourdieu, Scouler, and others; and some light has been cast on them by recent discoveries of plant remains in the trap-rocks of Antrim and of the Hebrides. The silicified wood is found in the drift deposits at Sandy Bay, to the east of the lough, near Crumlin, and is not confined to the lough shore, but is found far inland in many parts of the country to the east, and northwards beyond Randalstown; but on the west of the lough it occurs only on the beach, particularly about Black Point, in county Tyrone, to which it has been washed by the waves. The plant remains recently discovered near Ballyclare Station of the Northern Counties Railway, agree closely with the lignite found on the lough shore near Crumlin, and with the silicified wood. Large silicified trunks have been found under the Camlin River, near Crumlin, and one of these, now at Langford Lodge, is about ten feet high, and as many in girth. Another, which was described by Barton, originally weighed about 700 lbs. In certain places near Sandy Bay the silicified wood has been found in connexion with lignites, but it is not co-extensive with the lignites, nor does it, like them, occur intercalated between the masses of trap-rock. Near Lurgan, which is a few miles south of the lake, there is a deposit of lignite, accompanied with silicified wood. Eastward of this, we come to the great basaltic district of Antrim and Londonderry, extending over an area of 1200 miles in the north-east of Ireland, and re-appearing beyond the sea in the Scottish Hebrides and the F  roe Islands. It is necessary to bear in mind that the basaltic plateaux consist of many successive sheets, marking separate volcanic eruptions.\* In Antrim the sheets attain the thickness of 900 feet, and in Mull of 3000 feet; yet these figures do not at all represent their original thickness, as there must have been long and tranquil intervals between the successive outflows of the basalt. Since the last of these outflows, mountains and valleys have been removed by denudation, and new valleys excavated, and the time required for all these changes must have been enormous. We ought also to bear in mind that there occur amongst the basalts intercalated masses of carbonized vegetable matter, such as the coal-beds of Skye and Mull, and the leaf-beds of Mull; as also the coal-beds of county Antrim, and the lignites found at Knocknadona, near Lisburn, at Shane's Castle, and on the Northern Counties Railway, near Templepatrick. At the last-mentioned place there were found fragments of branches, with the leaves of coniferous trees, and the leaves of ordinary dicotyledonous trees, as well as those of sedges and grasses.† These plant remains agree very closely with the lignite found

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\* See Mr. Geikie's Article in Quart. Journ. Geol. Soc., Aug., 1871.

† See Mr. Bailey's Paper in Quart. Journ. Geol. Soc., Aug., 1871.

on the lough shore near Crumlin, and with the silicified wood. This amount of agreement does not render it certain that all these fossils belong to the same geological formation; but it favours this view, which is confirmed by other considerations. Thus it appears highly probable that all the petrified wood and the lignites, in common with the basalt, are to be referred to the miocene age, like the Bovey Tracy beds of Devonshire, and the corresponding formations in Mull and Skye, as well as the coniferous wood of Eigg.

What yet remains for determination is the stratigraphical relationship of the beds about Sandy Bay, in which the silicified wood is found associated with the lignites. That district, for a radius of several miles, is covered by a thick deposit of boulder clay, resting on trappean rocks.\* This boulder clay or drift is of post-pliocene age, and contains fragments of basalt and other rocks which have travelled further. It is observed that the clay partakes of the character of the subjacent rock, from which we may infer that, if the fossil vegetation belonged originally to the age of the basalts, it would have subsequently found its way through the glacial action of the post-pliocene era to the clay beds where it now occurs. The superficial drift contains no shell or other fossil save the silicified wood, with fragments of cretaceous fossils and of chalk. Dr. Dawson, of Montreal, describes† a closely similar drift in Canada, containing drifted pieces of coniferous wood; he supposes the formation to have been deposited by floating icebergs, and accounts for the absence of shells by the supposed rapidity of deposition.

The specimens of silicified wood vary in size, hardness, and in degree of silicification.‡ When with lignites, they are dark-coloured, easily split or crumbling, resembling bog-fir in texture. When long exposed to the atmosphere, or when occurring as boulders in the drift, they are bleached, so that they were thought to be holly; but the internal parts remain black. Even the darker varieties on being burnt become white. Sometimes they consist of a mixture of carbonaceous and siliceous matter, and the wood structure is obsolete. Generally, however, the structure is quite distinct, and when large trunks have been found, the cavities are covered with minute crystals of quartz, and sometimes with a layer of chalcedony. Bischof represents a specimen which he analysed as containing 97·71 per cent. of silica, a little peroxide of iron, and not much more than 1 per cent. of organic matter.§ On ignition, an empyreumatic odour was felt, which may be due to resinous matter enclosed in the silicified fibre.

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\* See Explanatory Memoirs to accompanying Sheet 36 of Maps Geol. Surv. Irel.

† "Leisure Hour," 1871, p. 716.

‡ See Dr. Scouler's Paper in *Dubl. Geol. Journ.*, Vol. I.

§ Dr. Hodges states that he found a much larger proportion of organic matter present, perhaps 20 per cent.

A microscopic examination shows that the delicate structure of wood is still retained, but instead of being holly, it is the wood of coniferous trees, as is proved by the rounded discs in the wood-cells. Barton made a close guess when, judging from the smell, he set it down as cedar wood. The *coniferae* do not seem to have been the only trees living at the particular time and place to which they belonged, for leaves of alder and beech, and of other ordinary exogenous trees, as well as of *coniferae*, have been recently found at Sandy Bay by Mr.

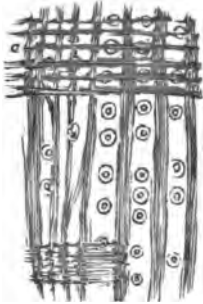


Fig. 1.

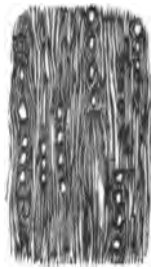


Fig. 2.



Fig. 3.

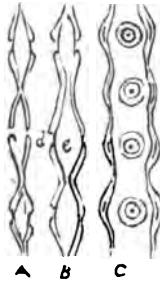


Fig. 4.



Fig. 5.

M'Henry, of the Geological Survey. Dr. Carpenter states that the wood of *coniferae*, palms, and arborescent cryptogams is preserved where the harder wood of oak, elm, and beech decays.\* The British miocene flora was very luxuriant, having evergreens like the fig, evergreen oak,

\* Vegetable Physiology, § 861.

custard apples, vines, with palm trees, and ferns, and the coniferous sequoia. That was an age of warmth in northern regions; and we may have in the silicified fossils the only representatives of a rich and varied vegetation. The wood of *conifera* is remarkable for the absence of vessels or ducts, and for having tubular wood-cells covered by rows of circular discs on the sides facing the medullary rays, whilst the medullary rays themselves bear smaller discs. Our figures (1 to 5) represent the different sections of the wood of the common deal (*Pinus Strobus*). Fig. 1 represents a longitudinal section, and Fig. 2 a view in the direction of the radius of the longitudinal sections of the disc-bearing wood-cells. Fig. 3 represents the transverse section, when we look down into the tubes of the long cells. They appear crowded densely together at the autumn growth, so as to mark the boundaries of the growths of two successive years. Figs. 4 and 5 represent the discs of Fig. 1 still more highly magnified. Fig. 6 represents the duct of a nonconiferous plant (the common lime tree), *Tilia Europæa*, and is given for the sake of comparison. The white spots in Fig. 2 mark the ends of the medullary rays which appear passing out from one to another.

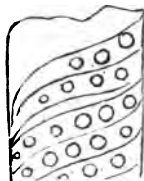


Fig. 6.

There are two leading divisions of coniferous wood—

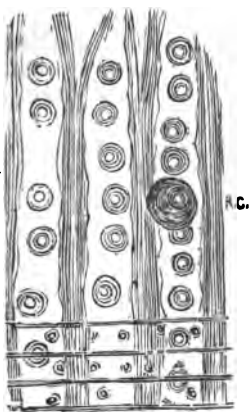


Fig. 7.

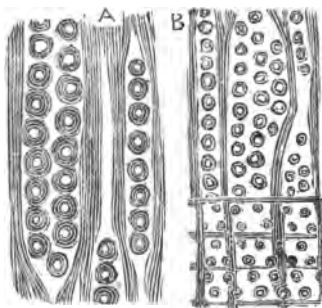


Fig. 8.

(1). The *Pine* division, where the discs are usually *detached* and in *single* rows, or if the rows are double the discs stand opposite to each other. Figs. 1 to 5 represent this division, as also does the wood of juniper, fig. 7, (*Juniperus communis* L.).

(2). The *Araucarian* division, in which the discs are in *single*,

double, or triple rows, those in one row alternating with those of its neighbour. Where there is a single row, the discs are in contact with each other. When in triple rows they are crowded, and those in the centre row are perfect hexagons, from pressure. Fig. 8 (where A represents the *Dammara alba*, and B the *Eutassa excelsa*,) illustrates this division. In other kinds we find peculiarities; thus in *Taxus*, or Yew, there are spiral fibres in addition to large bordered pores, as in figs. 9, 10, 11.\*



Fig. 9.



Fig. 10.

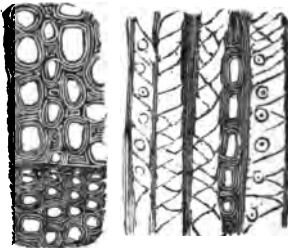


Fig. 11.

*Cycas revoluta* has bordered pores, each with a slit-like marking in the centre. The structure of *Taxodium* (Fig. 12) is somewhat similar; where the concurrence of two slits on the opposite sides of a tube-cell

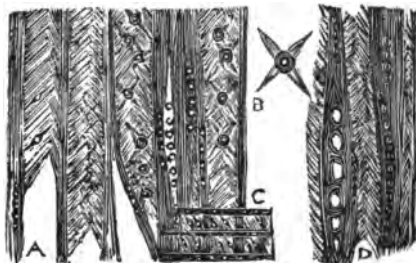


Fig. 12.

gives the appearance of a cross, as at B. D represents the tangential section, with the ends of the medullary rays, as in Fig. 2. *Ephedra* has

\* Fig. 9 is copied from *Catal. Histol. Series. Mus. Coll. Surgeons* (England) where, as also in *Quekett's Histology*, it is erroneously referred to *Araucaria*.

discs without the central dot. In some instances there are no discs. Further distinctions are got from the presence or absence of resiniferous cells or ducts.

The nature of these pores or disks has been a subject of controversy. They have been variously deemed glands, or tumours with holes to secrete turpentine, or spots in the cell-wall, or as discs with perforated centres. Mohl discovered them to be circular spaces, their thinnest parts being placed opposite each other, giving lens-shaped cavities

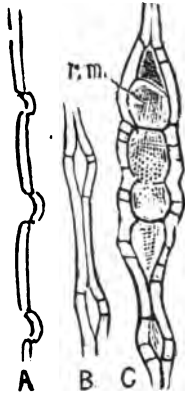


Fig. 13.



Fig. 14.

between the adjoining wood-cells, as seen in Figs. 4 and 13. Fig. 14 gives a transverse section of the wood tubes, with the matter of lignification separate on one side from the elementary membrane. At *aa* appear the pits on corresponding parts of adjoining cells; at *b* one appears without any corresponding one. Fig. 15 A is a section of two tube-cells, showing lens-shaped interspaces on opposite sides.

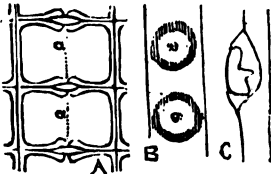


Fig. 15.

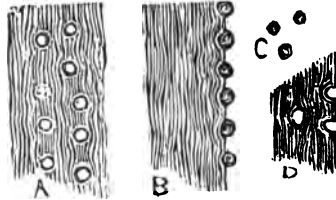


Fig. 16.

Light passes in the direction of *aa*, and is decomposed so as to present varying colours. C in this Figure, as well as Fig. 5, shows the

centre of the discs when seen in profile to bulge out. B represents two young discs. Fig. 16 represents silicified wood from Fredericksburg, in Virginia, showing at B small globular bodies, seen again detached at C; at A and D are the empty intercellular cavities which contained them.

Thus the discs consist of depressions in contiguous fibres, enclosing cavities, which may become filled up with intercellular matter. The thin wall in the centre is perhaps capable of distension according to the varying pressure of the enclosed gases. Schleiden thought they arose from spiral fibres in the young wood; but at fig. 15 B, the young discs appear as tumours with a central pit. The cells of the medullary rays also bear discs, which are much smaller than those of the wood-cells. From a consideration of the absence of these vessels or ducts in the wood of these trees, so that the ordinary wood-cells discharge the functions which are elsewhere shared between various kinds of vessels; of the absence of hard deposits in the wood-cells, which are thus long tubes; of the presence of spiral fibres in some cases to keep the tubes distended; of the intimate connexion between the vertical and horizontal growth, as evidenced by the medullary rays having discs in imitation of the wood-cells; of the close correspondence in position between the discs of adjoining wood-cells; and finally, from a regard to the habits of these trees, as tall, evergreen, rapidly growing trees, and as manifesting much circular uniformity in their growth, we may conjecture the functions which the discs perform. Easy communication is required in all directions through the trunks. The ascending sap has the long tubular cells to conduct it, and these tubes give passage to gases as well as liquids; the descending sap passes inwards by the soft and tubular medullary rays. The discs of the wood-cells aid in giving an easy passage round the stem to the fluids and gases; the leathery walls of these wood-cells would not allow the diffusion of the sap or gases in the circumferential direction; but as in other trees we have ducts with transparent walls, so we have here much of the wall on each side of the wood-cell reduced to the thin membranes of the discs. Of the three channels of communication, the vertical is the most active, next is the radial, and last is the circular. It is known that the relative conductivity for heat possessed by wood varies in the same order.

It is easy to assign any fragment of wood to the coniferous class, where we can detect these discs under the microscope. But when we come to inquire into the proper subdivision our difficulties increase. We have already considered the characters which mark the two leading divisions of this wood, and we have noticed subordinate peculiarities. Some writers have established genera and species of fossil coniferous wood, denominating all that resemble pine as *Pinites*, and all that resemble *Araucaria* as *Araucarites*; various specific marks have been derived from the character of the annual rings, the character of the cell-walls, the arrangement of the medullary rays, and the abundance or

rarity of resiniferous cells or ducts. Thus the Lough Neagh silicified wood is named by Kraus *Cupressoxylon Pritchardi*; the genus *Cupressoxylon* is described as "wood having narrow, distinct, concentric layers. Prosenchymatous cells porous, the pores large, round, in one or more series, opposite. Resiniferous cells very frequent. No resiniferous ducts. Simple medullary rays."

This group is represented by Cupressaceæ and Podocarpeæ of living coniferæ. It resembles Cedroxylon, being distinguished from it by having resiniferous cells, whilst cedar wood has resiniferous ducts. The *species* is characterized as having concentric layers of wood not very conspicuous, wood-cells thin walled, narrowing towards the boundary of the layer, discs in one or two series, minute, contiguous; medullary rays simple, rarely compounded of 1 to 25 cellules of large size; copious resiniferous ducts. Its only known locality is Lough Neagh.

As has been shown by Schimper ("Traité de Paléontologie Végétale," Paris, 1870), these distinctions are not to be relied on. For the genus *Pinus* alone can we get specific characters, and in other cases we must dismiss specific and generic distinctions. The wood called *Araucarites* is not necessarily the wood of *Araucaria*, but may belong to *Walchia* or some other genus, and the Lough Neagh silicified wood, though called *Cupressoxylon*, does not necessarily belong to *Cypressa*. Kraus has arranged all the varieties of coniferous wood into five typical groups:—

- 1.—Type of the Cupressaceæ (*Cupressoxylon*), comprehending Cupressaceæ, Podocarpeæ, and part of the Taxaceæ.
- 2.—Type of the Abietaceæ (*Cedroxylon*), including the genera *Abies*, *Picea*, *Larix*, *Cedrus*.
- 3.—Type of the Pines (*Pityoxylon*), including the genus *Pinus* and its sub-genera.
- 4.—Type of the *Araucaria* (*Araucarioxylon*), including *Araucaria*, *Dammara*, and some extinct forms.
- 5.—Type of the Taxaceæ (*Taxoxylon*), including all the genera of Taxaceæ, not included in type 1.

The first of these types, the *Cupressoxylon*, includes the Lough Neagh petrified wood, which may thus be regarded as representing some tree whose wood agreed with that of the cypress. The tribe of the Abietaceæ took the lead in the Tertiary European flora; whilst the Cupressaceæ occupy the second place. The *Sequoia* is intermediate between these orders, and attained its maximum during the miocene age, abounding even in the Arctic regions. As remains of it have been found in the Antrim basalts, and at Sandy Bay, our specimen may belong to it. Now it is confined to a strip of land beyond the Rocky Mountains of North America. It is probable that Europe possessed no species of *Cupressoxylon* during the pliocene or post-pliocene age, so that we are thus driven back to the miocene for the origin of the specimens found in the boulder clay.

Fig. 19 represents the silicified *Cupressoxylon Pritchardi* of Lough

Neagh. It will be observed to have a close resemblance to the wood of the common juniper (Fig. 7) and pine (Fig. 1).\*

As to the nature of the process of silicification, two different processes are popularly confounded under the term; (1) the incrusting



Fig. 19.

process, as at the geysers of Iceland. This is simply a deposition of silica from surcharged water, especially on its evaporation. Complete evaporation of the water is perhaps necessary, and hot water is favourable to the process. (2) Interstitial silicification, where the organic

\* We append a translation of Schimper's definition of the types of coniferous wood, or as they are sometimes denominated, genera.

A. Prosenchymatous cells *devoid of pores*, *Aporoxylon*, Ung.

B. Prosenchymatous cells *bearing pores*.

I. Pores *uniserial and distant, or opposite*.

a. Prosenchymatous cells *porous, without spirals*.

1. Parenchymatous (resiniferous) cells absent.

a. Cells of medullary ray *circular* on a transverse section, *Physematopitys*, Goepp.

b. Cells of medullary ray *oblong* on a transverse section, *Cedroxylon*, Kraus (*Pinites*, Goepp, *Peuce*, Ung. ex. p.).

2. Parenchymatous (resiniferous) cells very numerous; *Cupressoxylon*, Kr. (*Cupressinoxylon*, G., *Thuioxylon*, Ung.).

3. Parenchymatous cells numerous; resiniferous ducts present. *Pityoxylon*, Kr. (*Pinites*, G., *Peuce*, Ung. ex. p.).

b. Prosenchymatous cells *porous with spirals*.

1. Medullary rays *porous*. *Taxoxylon*, Kr. (*Taxites*, G., *Taxoxylon*, Ung. ex. p.).

2. Medullary rays *porous, with spirals*. *Spiropitys*, G.

II. Pores *uniserial and contiguous, or pluriserial, and spirally arranged*.

a. Pores *round or polygonal from contact*.

1. Medullary rays *simple* (uniserial) *Araucroxylon*, Kr. (*Araucarites*, G., *Dadoxylon*, Endl.).

2. Medullary rays *compound* *Pissadendron*, Endl. (*Palæoxylon* Brongt?)

b. Pores *compressed, oblong*, *Protopytis*, Goepp.

matter is removed particle by particle, the delicate internal structure of the original organism being usually preserved. The Lough Neagh wood has undergone the second kind, or interstitial silicification. The process must have been caused by water containing silica in solution; but it was not due to the water of Lough Neagh, as that water is singularly free from earthy constituents, and is not known even to have any tendency towards silicification, and the lough did not exist as such at the time when the process took place. Nor can the adjoining soil or clay have produced any such effect, as it is only when dissolved in water that the silica can penetrate the structure of wood. Nor can the agent have been hot water or steam, as has been supposed in some quarters, for it would, in this case have reduced the ligneous matter to a pulp, and destroyed it. The water of rivers at ordinary temperatures has, in many instances produced such a phenomenon, even within the historical period, silicifying wood to a greater or less depth from the surface, and several illustrative cases, from the Danube, from a river of Saxony, from Egypt, and from America, are given in "Bischof's Chemical Geology." The waters of most rivers and of the sea contain a very small percentage of silica, which is sufficient to supply material for the process. Bischof lays down the rule, that the less soluble material replaces the more soluble in these circumstances. It is usually found that the change commences at the surface, so that the internal parts remain longest unsilicified, and often decay, whilst the outer shell becomes hard and stony; and, subsequently, the internal parts may become filled up with a foreign matter, as sand. Soft wood may be most easily preserved, as the silicifying process will here most rapidly penetrate to the heart of the trunk before it has time to rot. Thus the silicified wood is usually hardest at the circumference, and softer in the centre.

Hence we may sum up our observation by stating that—

(1.) The petrified wood under examination was coniferous, of the type *Cupressoxylon*; and may have been of the genus *Sequoia*, but this is uncertain.

(2.) There is an intimate connexion between this silicified wood and the lignites of Antrim. It is never found in conjunction with the lignites in the basalt, but it is found with those in the boulder clay; and a comparison of the two groups of lignites with each other, and with the silicified wood, is in favour of the view that the latter is a representation of miocene vegetation.

(3.) The process of silicification is probably due to cold water holding silica in solution, as it often occurs in the water of running rivers. The time required for transmutation must have been great, so the notions that the change takes place in seven years, that the wood changed is holly, and that the silicifying agent is the water of the lake, are erroneous; as are also the opinions that the wood was araucarian, that the change was due to the soil of the adjoining country, that such process is still in progress, or that it was caused by the agency of hot water or steam, charged with silica.

(4.) The geological age to which it is due may be fairly conjectured. It is found in post-pliocene clay, to which it was transferred, after silicification, from its original bed. The connexion with the lignites, as well as the structure of the wood, and the comparison of successive tertiary floras, point to the *miocene* as to its original date. The fact that only the one kind of wood occurs in a silicified condition does not imply that it was the only tree existing at the time in its habitat.

(5.) A consideration of the circumstances under which silicification takes place may help us in picturing the state of things in which this wood was silicified.

A rapidly-flowing river, containing silica in solution, and having logs of trees in its channels, would afford favourable conditions for the production of silicified wood, and we may thus guess at the origin of that for which the neighbourhood of Lough Neagh is celebrated. The Antrim system of trap-rocks forms part of a more extensive system, which includes the Hebrides, much of Scotland, and islands north of Scotland. All this district, during the miocene age, constituted part of a continuous continent. Its northern parts were occupied by mountains covered with luxuriant forests, and watered by large rivers. Mr. Geikie has recently discovered the bed of one of these rivers under the Scur of Eigg, one of the Hebrides; and fragments of coniferous wood have been found there, which Lindley and Hutton call *Pinites*, and which has been silicified like that of Lough Neagh, but which belongs to a different coniferous type. In the island of Mull silicified wood has been found, agreeing substantially in external characters with that which we are describing; in fact, the elaborate description of it which Mr. Nicol gave forty years ago, would apply in every word to the Lough Neagh specimens. Many rivers must have flowed southward over the basaltic continent of the miocene age, and we may possibly find an explanation of the petrifying process by supposing the petrified logs to have grown as forest trees in the mountains north-west of Scotland. Lignite beds were formed by swamps, and masses of lignite would be transported by floods. Logs of trees might be silicified in such rivers, and some of these be buried up under subsequent outflows of basalt. Then the glacial action of the post-pliocene age may have transported some, the original locality of which may have been since destroyed by denudation, to the Neagh district, wearing and rounding them, and at last leaving them in its clay-drift. This is only a fancy picture, but it is the best attempt we can make to realize the conditions under which these remarkable fossils may have been deposited.\*

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\* Through the kindness of my friend, Mr. William Gray, I have lately seen a specimen of partially silicified lignite, which was obtained intercalated between the beds of trap at Lawrencetown, near Banbridge. This is, I believe, the first instance of intercalated lignites in the Antrim-basalts being found in a silicified condition; and it confirms the conclusions suggested above.

XXXV.—ON THE FORMATION OF CRYSTALLINE MINERALS, HAVING THE SPHERICAL FORM. By CHARLES R. C. TICHBORNE, Ph. D., F. C. S., M. R. I. A., &c.

[Read June 11, 1873.]

WHEN a fluid is placed in another liquid, with which it is not homogeneous, the result is the formation of a spherical mass of perfect regularity, the sphere being due to the laws of gravity of mass. Thus if a drop of oil is allowed to fall into a beaker of spirit and water having the requisite gravity, the oil will float about as a perfect sphere—but if the specific gravity of the spirit be lowered by the addition of alcohol until the oil rests upon the bottom of the vessel, a hemisphere is produced similar to those so frequently seen in minerals of the wavellite class.

A large number of minerals are found having forms derived from this origin, or are simply modified spheres. Under this class come the forms technically known as Globular, Botryoidal, Mammillated, Reniform, Pisolitic, &c.\* A great number of the minerals so shaped are of an aqueous origin, and on consideration it will be self-evident that many of these minerals must have been at one stage of their formation, or deposition, existent as a fluid non-homogeneous with the general mass of the solution. This can be explained in the following manner:—

All are agreed, I believe, as to the possible existence of bodies in two states, as enunciated by Graham—colloids and crystalloids—and two distinct views may be taken of molecules in reference to these conditions. Thus a molecule may be specially a colloid or a crystalloid, as the case may be, or rather—as I would prefer to put it,—the colloid character shall preponderate as in gelatine, or the crystalloid properties as in chloride of sodium; and again, the molecule may be so altered in construction by heat or some other physical force as to be converted from a colloid into a crystalloid; e.g., the conversion into colloids by dehydration, and *vice versa*; secondly, we are compelled to acknowledge that a molecule may exist intact both in the colloidal and the crystalloidal condition. I hardly think stress enough has been put upon this important theory: thus rock crystal and calcedony may be viewed as natural examples of the colloid and crystalloid of silicic acid—whilst the opals may be viewed as transition minerals formed during the gradual dehydration of the pectized acid.

My theory, therefore, insists that minerals such as wavellite have been actually separated in the colloid form as a fluid non-homogeneous with the menstruum from which they are deposited, to enable them to

\* The author has already referred to this subject in an Addendum to a Paper on Molecular Dissociation by Heat; read before the Royal Irish Academy, April 24, 1871.

assume the peculiar appearance they ultimately present. If we substitute melted spermaceti for the oil in the experiment detailed in the opening paragraph of this Paper—or use any other substance capable of taking the crystalline form on cooling, we shall get an exact representation of this phenomenon. Thus the melted spermaceti is best dropped by a pipette into a layer of hot alcohol floating upon a layer of hot water: as the whole cools, crystals strike out from the periphery to the centre, and must not be confounded with some specimens where a foreign nucleus acts, as the starting point and the crystals radiate from the said nucleus.

This phenomenon is frequently produced in many laboratory operations, such as the crystallization of chlorate of quinia, lactate of lime, perchloride of iron, and valerianate of zinc. In some of these examples the salt is seen to be deposited at certain temperatures in colloid spheres, which after a little time become crystalline. But such phenomena are not very common in laboratory operations connected with the so-called inorganic molecules, for the simple reason that the temperature employed is not high enough to produce the dehydrated molecules which seem in many cases to affect the colloid condition.

That silica may exist in a crystalloidal, or at least in a modified colloidal condition, whilst in solution, may be prognosticated from the following observations:—

If a two per cent. solution of silica obtained by dialysis is allowed to remain in a closed vessel undisturbed for a considerable period, and if the room is free from vibrations, in time the silica will be pectized and slowly deposited upon the sides of the vessel, but strange to say, always in sections of spheres which remain perfect as long as they are undisturbed. So deceptive is this, that at first sight the observer would hardly be persuaded that it is not a crystalline mass—but the slightest movement breaks through the illusion, and the deposit is found to be merely the ordinary flocculent silica, which, however, seems to have been deposited from a non-homogeneous fluid. If a beam of electric light be also passed through the liquid in course of pectinization, this is almost conclusively proved by the peculiar appearance foreign to a perfect solution.

To these observations we may add the important discovery of Graham, who says, “The ultimate pectization of silicic acid is preceded by a gradual thickening in the liquid itself. The flow of liquid colloids through a capillary tube is always slow, compared with the flow of crystalloid solutions, so that a liquid-transpiration-tube may be employed—a colloidoscope. With a colloidal liquid alterable in viscosity, such as silicic acid, the increased resistance to passage through the colloidoscope is obvious from day to day. Just before gelatinizing, silicic acid flows like an oil.”\*

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\* On the Properties of Silicic Acid and other analogous colloidal substances, by Thomas Graham. *Proceedings of the Royal Society*, vol. xiii., p. 336.

It would, therefore, appear that the crystalline silica is held in solution, whilst the colloid seems to be the modification of silica most prone to separate. These views, from the tone of the whole Paper, would seem to be those held by the late Professor Graham.

This peculiar form of crystallization is therefore indicative of a certain analogy of chemical construction, and may be actually used to diagnose the molecular structure of a complicated mineral. I received some time ago from Professor Storey Maxwell, of the British Museum, a small specimen of a rare mineral that he had named Andrews site, in honour of the President of the Chemical section of the British Association, 1871.\* It would seem from the discoverer's Paper to be a difficult mineral to analyze, but from the analysis it would appear to belong to a natural group of minerals which Professor Storey Maxwell has designated the Dufrenite Group, but which would for my purpose be better designated the Wavellite Group :—

Wavellite .	$2\text{Al}_2\text{P}_2\text{O}_7$	$\text{Al}_2\text{H}_2\text{O}_6$
Dufrenite .	$\text{Fe}_2\text{P}_2\text{O}_7$	$\text{Fe}_2\text{H}_2\text{O}_6$
Andrews site .	$3\text{Fe}_2\text{P}_2\text{O}_7$	$\text{Cu}_3\text{P}_2\text{O}_7$ $3\text{Fe}_2\text{H}_2\text{O}_6$

In the Wavellite and Dufrenite we have two minerals constructed with similar molecules, but in the Andrews site we have also the production of the tricupric salt from the presence of a nucleus of metallic copper which is almost invariably there. Andrews site was found by Professor Storey Maxwell to be extremely difficult to analyze, from the foreign substances mixed with it, and he seems to have arrived at the above formula after a careful chemical investigation ; but if any collateral proof were wanting of the correctness of this analysis, it would probably be its extraordinary physical resemblance to Wavellite. It is curious to observe how spherical forms in minerals preponderate in those constructed with colloid molecules.

We may have the same phenomenon occurring in igneous minerals. Such a case may be typified by the spherules of crystalline silicates found in devitrified glass. It is curious to observe the change of gravity which always occurs in such cases between the colloid and crystalloid (e.g. vitreous and devitrified glass). In the glass, and in many of the minerals, such as wavellite, there are no nuclei.

A specimen procured by myself from Messrs. Chance's Glass Works, and produced by over-heating, gave, on examination and analysis, the following characteristics :—It consisted of silicate of sodium, with 6 per cent. of lime and traces of iron, potash, and alumina. The specific gravity of the vitreous portion was 2.4° whilst the devitrified portion was 2.47. The devitrified portion was scattered through the mass in pieces about the size of small peppercorns, which were opaque—each mass being partially detached from the vitreous

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\* See Report of the Forty-first Meeting of the British Association at Edinburgh, 1871, page 75.

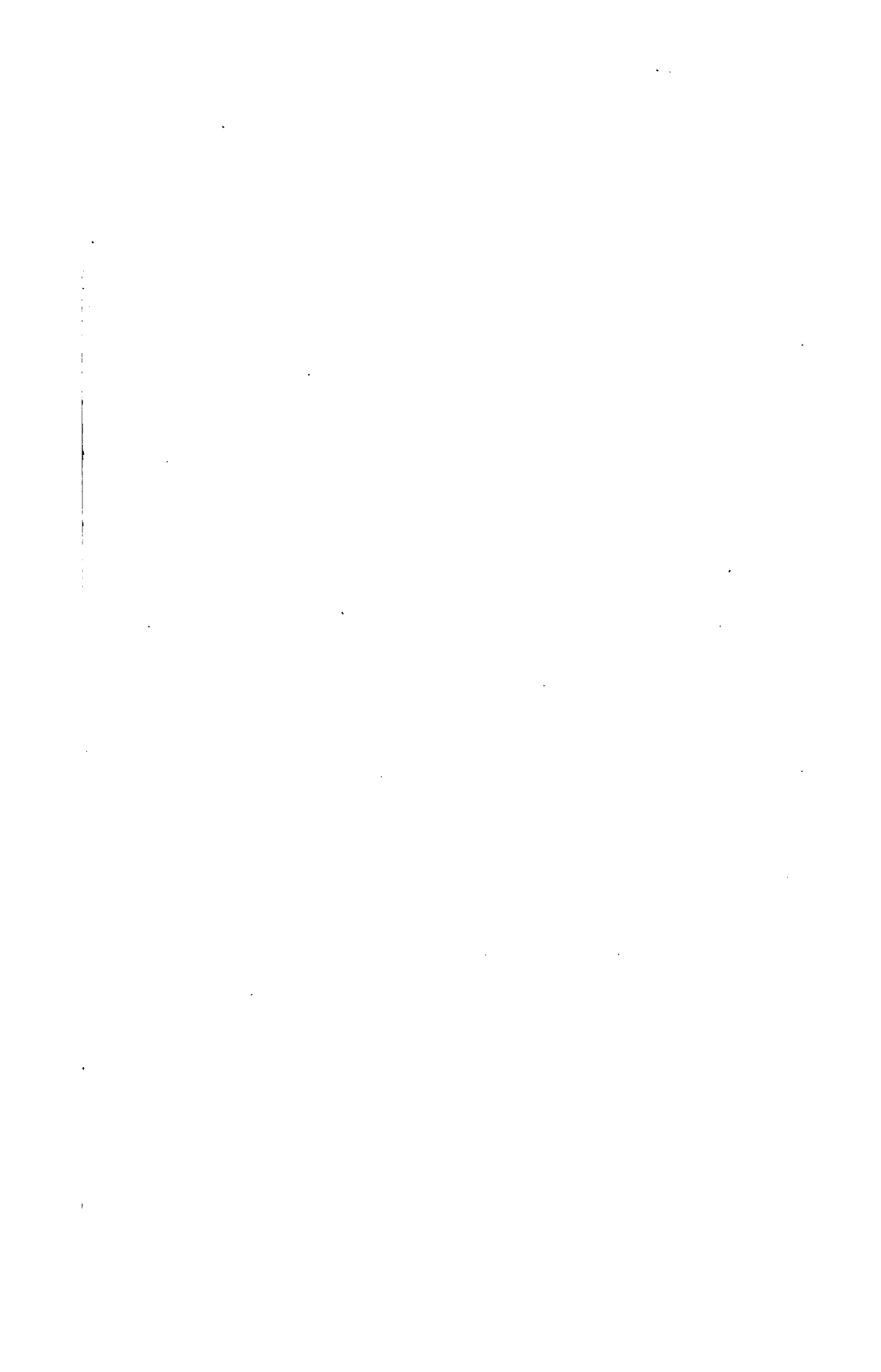
portion by a fracture surrounding the crystalline sphere, and which fracture consisted of vacuous space. A section made so that it cuts through the axis of one of the warty masses, shows them to be crystalline spheres, more transparent towards the centre, the great opacity of the periphery being due to the suddenness and therefore minuteness of the crystallization. This proves that the crystallization proceeds outwards from the periphery and that a more regular and perfect crystallization takes place at the centre. It must be remembered that the actual fusing point of the crystalline portion is higher, and can never be remelted at the fusing point of the vitreous portion. It therefore follows that we must in this case, as in those mentioned in the first part of this Paper, consider those crystalline portions as existing as liquid masses independent of the general mass.

It is not intended to put down all the numerous radiating forms known as reniform, and the stalactic shapes as having been produced exactly by this method—that is to say, we are not prepared to prove that all such minerals must have been formed from one of two non-homogeneous fluids—but we do wish to convey that many minerals are evidently so formed, and that the change from the colloid to the crystalloid condition of the molecules in most of the other cases conduce to those characters which render these minerals peculiar.

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